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Light and Intermittent Smoking among Young Adults: Trends and Transitions

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Abstract

Light and Intermittent Smoking among Young Adults: Trends and Transitions

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Although smoking prevalence has declined, very light smoking (5 or fewer cigarettes per day) is still very common among young adults. The limited available literature indicates that emerging alternative tobacco use may play a role in the prevalence and progression of very light smoking among young adults. The current dissertation involved two studies examining trends and transitions of very light smoking and investigating the demographic and behavioral corelates of these trends and transitions. Study 1 fills the research gap by examining the trends of light smoking among young adults (18-25 year) during the past decade. The roles of demographic factors (such as sex, race/ethnicity, age group, and educational status) and other tobacco use status (such as daily smoking status and use of alternative tobacco) in trends of light smoking among young adults were also explored. The research sample was selected from the public national database, the NSDUH (National Survey on Drug Use and Health), 2002-2015. Findings suggested that the long-term smoking trends among young adults were nonlinear and the trends varied in different subgroups of young adults. The general decline in very light smoking among young adults masks the different

trends in certain time periods, tobacco use groups and demographic subpopulations. Tailored policies and prevention programs are needed to benefit subpopulations of young adults. Study 2 examines transitions of cigarette smoking among college students across two and half years using six semi-annual waves of online data from the Project M-PACT study (Marketing and Promotions Across Colleges in Texas), supported by the National Cancer Institute and the FDA Center for Tobacco Products (CTP). Using Markov models, the author examined changes in states of current smoking among college students within time intervals of various duration, and also investigated the roles of sex and alternative tobacco use in smoking status and transition. The results showed that the transitions of smoking status among college students were associated with starting smoking status, the duration of the interval, sex and the use of alternative tobacco products. These findings highlight the need to identify priorities for tobacco control programs and policies among college students.

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CHAPTER ONE: INTRODUCTION

Although cigarettes remain the most prevalent form of adult tobacco use, in recent years, the changing landscape of tobacco products and emerging tobacco use patterns has raised additional health concerns. Since the United States Surgeon General first reported tobacco-related health risks in 1964, tobacco use has been declining in the general population (Al-Delaimy et al., 2007; Jamal et al., 2015). However, this decline has been mainly attributed to decreasing numbers of daily smokers who consume cigarettes at high intensity (Jamal et al., 2015) and the decline has stalled in the past two decades (Garrett et al., 2011; Jamal et al., 2015). Concurrently, tobacco use patterns are evolving: low-level cigarette smoking, non-cigarette tobacco use, and multiple tobacco product use (i.e. use more than one type of tobacco product) have become more and more widespread (Backinger et al., 2008; Jamal et al., 2015; Lee, Hebert, Nonnemaker, & Kim, 2014; McMillen, Maduka, & Winickoff, 2012).

Despite the changing culture and substantial progress that has been made toward tobacco control, tobacco remains a leading cause of preventable deaths in the United States (Jamal et al., 2015). Previous research reveals that tobacco use in any form carries health risks (Bjartveit & Tverdal, 2005; Schane, Ling, & Glantz, 2010). However, traditional measurements and research methods of tobacco use might not be sufficient to understand the complexity of evolving tobacco use patterns. Moreover, both long-time trends and longitudinal research are required to document the changing practices of tobacco use and to advance tobacco control strategies.

This dissertation explores tobacco use patterns among young adults. Young adult tobacco use is of particular importance for two main reasons. First, young adulthood is an important developmental period for health behaviors. Second, emerging patterns of tobacco use, including

light and intermittent smoking, alternative tobacco use and multiple tobacco use, are particularly prevalent among young adults. The US Surgeon General's report of 2012 highlighted the importance of reducing young adults' initiation and use of tobacco products (US Department of Health and Human Services, 2012).

Young adulthood, spanning ages eighteen through the twenties (Arnett, 2005; Arnett, 2000), is a critical developmental period for engaging in many health-related behaviors, including tobacco use (Orlando, Tucker, Ellickson, & Klein, 2004). Frequently, the initiation of tobacco use and the establishment of regular or heavy cigarette use occurs during the young adult years (Everett et al., 1999; Rath, Villanti, Abrams, & Vallone, 2012). Data from the 2011 Legacy Young Adult Cohort Study showed that 32 percent of tobacco users began using tobacco products after the age of 18 and 39 percent of regular users began regular use between the ages of 18 and 34 (Rath et al., 2012). Similarly, data from the National Survey on Drug Use and Health (2010) showed that almost one third of adults who smoke daily progressed to this level of use during young adulthood (US Department of Health and Human Services, 2012). Moreover, the tobacco industry has invested intense efforts into studying young adult development and has used skillful marketing strategies to attract potential smokers by manipulating smoking motivations and social environments.

According to a recent report from the National Survey on Drug Abuse and Health, young adults aged 18 to 25 had a relatively high rate of tobacco use compared to other age groups (Center for Behavioral Health Statistics and Quality, 2015; Hu, 2016). Light and intermittent cigarette smoking is a particularly prevalent smoking pattern among young adults. The use of alternative tobacco products, especially emerging types such as hookah and electronic cigarettes, is higher among young adults (Hu, 2016) than among other age groups (Kasza et al., 2017). In

addition, young adults have the highest rate of multiple tobacco product use (Lee, Hebert, et al., 2014), and most young adult users of multiple tobacco products smoke cigarettes concurrently (Soneji, Sargent, & Tanski, 2016).

Few studies have examined the trends of tobacco use among young adults, and even fewer have related trends of tobacco use to different subgroups of young adults. National representative data have indicated that very light smoking (<5 cigarettes per day [cpd]) increased among young adults from 1991 to 2002 (Pierce, White, & Messer, 2009) and from 2008 to 2010 (Substance Abuse and Mental Health Services Administration, 2012). However, light and intermittent smoking trends have not been consistently examined in recent years. Studies using nationally representative annual surveys showed that some alternative tobacco products, such as e-cigarettes and hookah, have gained popularity rapidly in recent years (Gilreath et al., 2016; King, Alam, Promoff, Arrazola, & Dube, 2013; Maziak et al., 2015; Rath et al., 2012) while other products such as cigars and smokeless tobacco stayed relatively stable over the past decades (Agaku et al., 2014; SAMHSA, 2014). However, trends of tobacco use among young adults over the past decade have not been fully explored.

The transition to and progression of light and intermittent smoking over time is still not understood. Light and intermittent smokers, who smoke less than daily and no more than 5 cpd on days of smoking (Husten, 2009), typically feel that they can control their ability to maintain low cigarette consumption (Ling & Glantz, 2004), however, they may maintain low levels of cigarette consumption because of psychological dependence. However, previous studies present conflicting evidence about the transition of smoking status. Some longitudinal studies have shown that low stable cigarette consumption is the most common smoking trajectory over time (Caldeira et al., 2012), and a substantial percentage of light and intermittent smokers maintain a

low smoking level after 1-4 year follow-ups (Caldeira et al., 2012; Levy, Biener, & Rigotti, 2009). However, other studies indicate that only a very small portion of baseline light and intermittent smokers report stable consumption over time (Hukkinen, Kaprio, Broms, Koskenvuo, & Korhonen, 2009; White, Bray, Fleming, & Catalano, 2009; Zhu, Sun, Hawkins, Pierce, & Cummins, 2003). Light and intermittent smokers were reportedly more likely than heavier smokers to be planning to quit and/or to have a higher self-efficacy for quitting (Boulos et al., 2009); however previous research has also suggested that light and intermittent smokers are less motivated to quit (Bondy et al., 2013; Etter, 2004) and that after attempting to quit, they have relapse rates similar to those of heavy smokers (Choi, Okuyemi, Kaur, & Ahluwalia, 2004).

It is particularly important to understand transitions of smoking status and the effect of alternative tobacco use on transitions among college students because this population represents 35%-40% of young adults (Snyder, de Brey, & Dillow, 2016). Although college students are less likely to smoke heavily than their non-college-attending peers, they are equally likely to be light or intermittent smokers (White et al., 2009). In addition, the transition into and out of college poses a unique developmental challenge for behavior change (Fromme, Corbin, & Kruse, 2008). College students are at elevated risk for light and intermittent smoking and concurrent use of tobacco products.

Previous studies indicated that tobacco use patterns vary across different subgroups of young adults with regard to sex, age, race/ethnicity, socioeconomic status, college status, smoker identity, age of smoking initiation, reasons to smoke (such as smoking for social reasons), previous attempts to quit, attitudes toward cigarettes, response to situational factors (such as environmental cues and stimuli), nicotine dependence and depression (Coggins, Murrelle, Carchman, & Heidbreder, 2009; Darlow & Lobel, 2012; Klein, Bernat, Lenk, & Forster, 2013;

Reyes-Guzman et al., 2017; Shiffman et al., 2014; Thrul, Ferguson, & Bühler, 2016). Evidence suggests that light and intermittent smoking is relatively common among women, singles, ethnic minorities and people with higher socioeconomic status compared to other subpopulations (Etter, 2004; Hukkinen et al., 2009; Levy et al., 2009; Okuyemi et al., 2002; Trinidad, Perez-Stable, White, Emery, & Messer, 2011). However, few studies have examined the trend of light and intermittent smoking among different subgroups of young adults; even fewer have investigated how transitions of smoking behavior among young adults are associated with other psychosocial or behavioral factors. Therefore, more studies are needed to determine how tobacco use patterns and progressions are associated with demographic and behavioral correlates.

The present study focuses on young adults (age 18-25) and explores this population's trends and transitions of very light smoking (no more than 5 cpd during the past 30 days). In addition, this study investigates the demographic and behavioral correlates of trends and transitions of light and intermittent smoking among young adults. To fulfill these research purposes, two separate studies were conducted.

Study 1 fills the research gap by examining the trends of very light smoking among young adults (18-25 year) during the past decade. The roles of demographic factors (such as sex, race/ethnicity, age group, education level, and education status) and other tobacco use status (such as daily smoking status and use of alternative tobacco) in trends of very light smoking among young adults were also explored. The research sample was selected from the public national database, the NSDUH (National Survey on Drug Use and Health) (Substance Abuse and Mental Health Services Administration, 2017), 2002-2015. Since 1971, NSDUH has been conducted annually to collect national data on substance use among individuals aged 12 years or older in the United States. Each year, NSDUH employs a state-based design with an

independent, multistage area probability sample within each state and the District of Columbia, using computer-assisted interviewing questionnaires. Since 2002, questionnaires and measurements related to tobacco use behaviors have been generally consistent over time. Data from the most recent 14 years (2002–2015) will be used to assess trends of light and intermittent smoking and alternative tobacco use. Logistic regression models will be used to test for linear and non-linear time trends, using orthogonal polynomials to model time simultaneously in linear and quadratic models.

Study 2 examines transitions of cigarette smoking among college students across two and half years using six semi-annual waves of online data from the Project M-PACT study (Marketing and Promotions Across Colleges in Texas), supported by the National Cancer Institute (NCI) and the US Food and Drug Administration (FDA) Center for Tobacco Products (CTP) (Creamer et al., 2016; Loukas et al., 2016). Based on cigarettes smoked per day (cpd) during the past 30 days, smoking status is categorized as non-smoking (0 cpd), very light smoking (<=5 cpd), and heavier smoking (>5 cpd). Using Markov models, the author examined patterns and changes in states of current smoking among college students within time intervals with various duration. We also investigated the roles of sex and alternative tobacco use in smoking status and transition over two and half years.

The dissertation studies fill gaps in our understanding of young adults' increasingly complex tobacco use trends and trajectories. Since the landscape of tobacco use has been evolving in recent years, more studies are needed to investigate the patterns, trends and transitions of tobacco use behaviors among young adults. The author examines the national representative trends of light and intermittent smoking and alternative tobacco use by demographic and behavioral correlates. This study also extends the literature by investigating the transition of light and

intermittent smoking and the role of alternative tobacco in smoking transitions among college students.

These two dissertation studies make methodological contributions to tobacco research. As light and intermittent smoking has become more and more prevalent, traditional measurement of smoking status such as lifetime cigarette smoking criteria and definitions of very light smoking may not be appropriate to study contemporary practices of very light smoking. The studies integrate both variable-based analysis and person-centered analysis (Muthen & Muthen, 2000). Variable-centered approaches are used to examine differences between subgroups and associations among study variables (e.g., if alternative tobacco use is associated with very light smoking status), whereas person-centered approaches (e.g., Markov models) are used to examine variability in individual trajectories and transitions across time.

CHAPTER TWO: REVIEW OF THE LITERATURE

Despite the past 50 years of health warnings, in 2014 an estimated 66.9 million people aged 12 or older were still using tobacco products, including 55.2 million cigarette smokers (Center for Behavioral Health Statistics and Quality, 2015) in the United States (US). Since 1964, a series of Surgeon General reports have consistently documented that smoking and tobacco use have serious health consequences, leading to millions of preventable deaths each year. According to the 2014 Surgeon General's report, each year an estimated 480,000 people die prematurely from tobacco related diseases, and more than $300 billion is spent in direct health care expenditures and productivity losses from tobacco-related issues (USDHHS, 2014). The overall mortality rate among smokers in the US is about three times higher than that among people who never smoked, and the life expectancy for smokers is at least 10 years shorter than for nonsmokers.

The diseases caused by tobacco use include but are not limited to: cancers, cardiovascular diseases, respiratory diseases, reproductive problems, oral diseases, skin problems, premature aging, premature and still birth, and other health problems such as hip fractures, low bone density and peptic ulcer disease (USDHHS, 2014). Tobacco use is also reported to be associated with mental illness (CDC, 2013; Lawrence, Mitrou, & Zubrick, 2009; SAMHSA, 2014) such as anxiety and depression, and with a cluster of risky behaviors such as suicidal behavior (Breslau, Schultz, Johnson, Peterson, & Davis, 2005), excessive alcohol use, and illicit drug use (SAMHSA, 2014).

Environmental restrictions and social norms about smoking have changed substantially over the past 50 years. Compared with the mid- to late 20th century, people are now better

educated about the harms of smoking. Cigarette smoking is widely banned in both indoor and outdoor public locations. Enforcement of policies that ban marketing and retail sales makes cigarettes less accessible to youth. However, gender differences of tobacco use have greatly narrowed (US Department of Health and Human Services, 2012), with men's smoking reduction greater than women's.

The studies conducted in this dissertation will research tobacco use behaviors among young adults, with a focus on emerging tobacco use patterns such as light and intermittent smoking and alternative tobacco use. The first study will examine trends of light/intermittent smoking among young adults (18-25 year) during the past 14 years using national data from the NSDUH (National Survey on Drug Use and Health), 2002-2015. The second study will examine transitions of cigarette smoking status among college students across two and half years using six semi-annual waves of online data from Project M-PACT study (Marketing and Promotions Across Colleges in Texas) (Creamer et al., 2016; Loukas et al., 2016).

Most existing tobacco-related studies have focused on the general adult population, and comparatively little research has explored young adult smoking patterns. The limited existing scholarship on tobacco use falls into several main modes of analysis: patterns and trends of tobacco use in recent years; health consequences of different tobacco use patterns; determinants and transitions of smoking behavior in young adulthood; and college students as a special group of young adults. The following review of literature summarizes what has previously been investigated and sets the stage for the studies in this dissertation.

Tobacco Use in the United States

Due to targeted public health efforts, both tobacco consumption and rates of tobacco use have decreased considerably over the past five decades in the United States (Al-Delaimy et al., 2007; Substance Abuse and Mental Health Services Administration [SAMHSA], 2012, 2015; USDHHS, 2014). However, in 2014, about one fourth of people aged 12 or older were still current (within the past month) users of a tobacco product, and the majority of these tobacco users were current (within the past month) cigarette smokers (SAMHSA, 2015).

The landscape of tobacco use has been evolving in recent years. During the past 50 years, people became better educated about the harms of smoking, cigarette smoking has been widely banned in both indoor and outdoor public locations, and marketing and retail sales to youth have been banned. Although the overall rate of cigarette smoking has declined, certain patterns of cigarette smoking, i.e. light and intermittent smoking, also referred to as *low level/rate smoking* or *chipping*, have increased and become the predominant form of tobacco use in some groups. The prevalence of some alternative tobacco products (ATPs) such as cigars, pipes and smokeless tobacco has remained relatively stable over the past decades (Agaku et al., 2014; SAMHSA, 2015), while other products, referred to as *emerging or novel tobacco products*, such as electronic cigarettes and hookah, have been gaining popularity rapidly in recent years (Gilreath et al., 2016; King, Alam, Promoff, Arrazola, & Dube, 2013; Rath et al., 2012). The rise in alternative tobacco product use has increased concerns about the co-use of several kinds of tobacco products. Researchers have noticed the changing landscape of tobacco use and started to investigate emerging tobacco use patterns. However, existing evidence remains limited, and more studies are needed.

TRENDS OF CIGARETTE SMOKING

The rate of traditional cigarette smoking has been declining among the general population. The decline has been manifested in several different ways: the reduction in size of the smoking population, the decline in smoking intensity, and decrease in smoking initiation (Jamal et al., 2015). According to the most recent national surveys, among the potential smoking population (aged 12 or older), estimated current cigarette smokers (used cigarettes during the past month) declined from 61.6 million (26.0%) in 2002 to 55.2 million (20.8%) in 2014 (SAMHSA, 2015). The numbers and rates of daily smokers, especially high-intensity daily smokers who smoked over 15 cigarettes per day (cpd), decreased from 1965 to 2014 (Jamal et al., 2015; Pierce, Messer, White, Cowling, & Thomas, 2011; Schoenborn, Adams, & Peregoy, 2013). In addition, declines were observed in the average number of cigarettes smoked per day among daily smokers, from 16.7 in 2005 to 13.8 in 2014 (Jamal et al., 2015).

Despite the above-mentioned reductions, cigarettes remain by far the most common form of tobacco product used in the US, and the decline in adults' usage has stalled in the past few years (Garrett et al., 2011). It is also noteworthy that while smoking prevalence has declined in the US from 2005 to 2014, the number of non-daily smokers (those who smoked some days during the past 30 days) increased from 8.7 million to 9.3 million, and the percentage of those who smoked 1 to 9 cpd increased from 16.4% to 26.9% among all current smokers (Jamal et al., 2015).

Although most studies of smoking behavior have often considered current smokers to be a homogeneous group, some researchers distinguish non-daily low-level smoking from high-intensity smoking. The phenomenon of smoking non-daily and at the rate of fewer than 5 cpd

was defined as “chipping” by Shiffman (Shiffman, 1989). Tobacco chipping is also referred to as very light smoking (Presson, Chassin, & Sherman, 2002; Sayette, Martin, Wertz, Shiffman, & Perrott, 2001; Shiffman, 1989; Wellman, DiFranza, & Wood, 2006), low-rate smoking (Etter, 2004; Zhu, Sun, Hawkins, Pierce, & Cummins, 2003), low-level smoking (Hyland, Rezaishiraz, Bauer, Giovino, & Cummings, 2005; Kenford et al., 2005), or light smoking (Bjartveit & Tverdal, 2005; Hukkinen, Kaprio, Broms, Koskenvuo, & Korhonen, 2009). These definitions have also been used interchangeably with the following terms: non-daily smoker, some-day smoker, intermittent smoker, and occasional smoker (Husten, 2009). Recent studies showed that intermittent smokers smoked about 4 days per week, and about 4 cpd on smoking days (Shiffman et al., 2012).

Tobacco use at any level is a significant health hazard (Bjartveit & Tverdal, 2005; Schane et al., 2010). Light and intermittent smoking, even as little as 1-5 cpd, has been associated with chronic diseases such as cardiovascular diseases and cancer (An et al., 2009; Schane et al., 2010), as well as other health risks such as future nicotine dependence (Okuyemi et al., 2002) and substance use (King & Epstein, 2005). In addition, light smoking may contribute to the worsening of mental health (Berg et al., 2012), and poor mental health may exacerbate tobacco use (Barnett et al., 2013; Pratt & Brody, 2010), both of which impair physical well-being and reduce quality of life (Leung, Gartner, Hall, Lucke, & Dobson, 2012).

Evidence has suggested that light and intermittent smokers are distinguishable from heavier smokers by their demographic characteristics, psychosocial profile, and nicotine dependence level (Fagan & Rigotti, 2009; Husten, 2009, 2009; Okuyemi et al., 2002; Sutfin, Reboussin, McCoy, & Wolfson, 2009; Wilson, Parsons, & Wakefield, 1999). Light and intermittent smoking is relatively common among young people, women, singles, ethnic

minorities, and people with higher socioeconomic status compared to other subpopulations (Etter, 2004; Hukkinen et al., 2009; Levy et al., 2009; Okuyemi et al., 2002; Trinidad et al., 2011). In comparison with daily or heavier smokers, light and intermittent smokers demonstrate noticeable day-to-day variability in cigarette consumption; they are also more likely to self-identify as nonsmokers, to smoke when socializing or drinking alcohol, to show fewer signs of nicotine dependence, and to be motivated or ready to quit smoking (Coggins et al., 2009; Levy et al., 2009; Robertson, Iosua, McGee, & Hancox, 2016; Shiffman et al., 2012; Song & Ling, 2011; Villanti, Pearson, Cantrell, Vallone, & Rath, 2015). One study found that light and intermittent smoking status was unstable and the nature of smoking transition was associated with smoking history and subjective nicotine dependence (Bondy et al., 2013).

Light and intermittent smoking has been reported as a long-term behavior or a transitional behavior to or from daily or heavier smoking. Levy et al. (2009) followed a population-based cohort of adults over 4 years and assessed differences across four smoking categories: very light (<= 5 cpd) nondaily, very light daily, light (6 – 10 cpd), and heavier (>10 cpd). The results indicated that only a minority of light smokers progressed to heavier smoking at follow-up; light smokers who increased consumption were more likely to exhibit signs of nicotine addiction and to be in a social environment conducive to smoking. For very light daily smokers (≤ 5 cpd), the frequency of smoking was the major predictor of progression to higher levels of cigarette consumption; very light daily smokers were more likely to progress to regular use than very light intermittent smokers.

Traditional measures and criteria of smoking status variables may be inappropriate for some population groups such as young adults and ethnic minorities (Ryan, Trosclair, & Gfroerer, 2012) and former definitions of smoking status may result in biased estimates of smoking

behavior. For example, the lifetime consumption of 100 cigarettes criterion has typically been used to determine ever and current smoking (Bondy, Victor, & Diemert, 2009), but it might not be appropriate for light or intermittent smoking with other tobacco products (Ryan et al., 2012). Some studies have suggested that intermittent smokers among young adults could be categorized into different subgroups according to their different levels of smoking. Lenk et al. (2009) examined young adult smoking patterns and differentiated low (smoked 1-14 days in past month) from high intermittent smokers. They found that low intermittent smokers were much less likely than high intermittent smokers to accept a smoker identity, to smoke with friends, and to feel addicted. In a longitudinal study, Klein and colleagues (2013) examined trajectories and predictors of intermittent smoking among young adults. The sample was a cohort of 18-year old young adults who reported smoking 1-29 days in the past month at baseline. Three trajectories were identified after following the sample for 4 years: "low frequency" (average 6 days of smoking in the past month), "medium frequency" (average 12 days of past month smoking) and "high frequency" (average 18 days of past month smoking). Findings indicated that over the four-year research period, low intermittent smokers decreased smoking frequency, medium intermittent smokers retained relatively stable frequency, and high intermittent smokers increased smoking frequency. Schauer et al. (2016) assessed the trends of adult intermittent smoking using the 2000-2012 US National Health Interview Survey. They created a nine-level variable for nondaily smoking: low-cpd (1-2 cpd) low-frequency (1-7 days), low-cpd moderate-frequency (8-14 days), low-cpd high-frequency (15-29 days), moderate-cpd (3-5 cpd) low-frequency, moderate-cpd moderate-frequency, moderate-cpd high frequency, high-cpd (>=6 cpd) low-frequency, high-cpd moderate frequency, and high-cpd high-frequency. The most prevalent intermittent smoking pattern was moderate-cpd high-frequency smoking (20.2%), followed by

low-cpd low-frequent smoking (19.7%). Between 2000 and 2012, the general prevalence of intermittent smoking remained stable; however, the rate of low-cpd intermittent smokers (who smoked 1-2 cpd in 8-20 days during the past 30 days) increased.

In addition, previous studies have examined the heterogeneity of light and intermittent smoking in relation to different smoking histories. Nondaily smokers who previously smoked daily have been defined as "converted" intermittent smokers, and those who have never smoked daily are defined as "native" nondaily smokers. More than half of current light and intermittent smokers converted from daily smoking (Coggins et al., 2009; Fish et al., 2015; Nguyen & Zhu, 2009; Shiffman et al., 2012). Some studies contrast converted and native nondaily smokers on demographic, psychosocial, tobacco-related characteristics and behaviors. In general, compared with native intermittent smokers, converted intermittent smokers (ITS) are more likely to smoke more heavily and more frequently, to self-identify as smokers, and to report higher nicotine dependent levels (Scheuermann, Mburu, Mathur, & Ahluwalia, 2015; Shiffman et al., 2015, 2012). Pinsker and colleagues (2013) studied a sample of college student smokers and found that converted ITS were more likely to be ready to quit compared to native ITS. Shiffman et al. (2015) indicated that converted intermittent smokers reported greater changes in cravings and tended to progress more quickly to heavy smoking. Similar to intermittent smoking, the "converted" and "native" terminology has been used to describe light smokers. Converted light smokers are formerly heavier smokers who have reduced to lower levels of smoking; whereas native lights smokers always smoked at low levels. However, few studies have compared native light smokers to converted light smokers (Fish et al., 2015).

One distinctive characteristic of light and intermittent smokers is that they tend to perceive themselves as invulnerable to the adverse consequences of smoking due to their low

levels of consumption (Ayanian, 1999; Brown, Carpenter, & Sutfin, 2011). However, many light and intermittent smokers continue to use cigarettes although they are not physically addicted to nicotine, which challenges conventional ideas about smoking motivation. Pharmacotherapy and nicotine replacement therapies, which are appropriate for daily/regular smokers, may be ineffective with light and intermittent smokers. Traditional cessation programs may not be able to reach these light or intermittent smokers successfully.

In summary, although the overall smoking prevalence and average cigarette consumption has declined, light and intermittent smoking is still common. Although light and intermittent smokers are less likely to report nicotine dependence, they are less likely to accept the smoker identity. Light and intermittent smoking is a transitional behavior with factors related to the risk of progressing into regular smoking. However, the trends, protective factors, and risk factors of light and intermittent smoking have not been fully explored. Understanding light and intermittent smoking is key to project smoking rates in the future. Health researchers need to reexamine theoretical frameworks and remodel concepts of smoking motivation to address light and intermittent smoking (Fagan & Rigotti, 2009). New and innovative interventions are also needed in order to target light and intermittent smokers and their quitting processes.

USE OF ALTERNATIVE TOBACCO PRODUCTS

Faced with declining numbers of cigarette smokers and revenues, the tobacco industry has developed greater prominence and now promotes non-cigarette alternatives, including electronic cigarettes, cigars, hookahs, and smokeless tobacco (Kim, Arnold, & Makarenko, 2014; Lee & Kim, 2014; Mejia & Ling, 2010). Electronic cigarettes, also referred as e-cigarettes or electronic nicotine delivery system (ENDS) devices, heat liquids containing nicotine as well as

compositions of flavoring and other chemicals into an aerosol that users then inhale. There are varying and innovative types of e-cigarettes, including vaporizers, vape pens, hookah pens, e-pipes, and e-cigarettes (US Food and Drug Administration, 2016d). A cigar consists of tobacco wrapped in a tobacco leaf and may contain as much tobacco as a pack of traditional cigarettes. Cigars come in different sizes ranging from small cigars and cigarillos to larger cigars (US Food and Drug Administration, 2016a). Hookah tobacco is also known as water pipe tobacco or shisha and is consumed through a water pipe made of a head, body, bowl, and a hose containing a mouthpiece (US Food and Drug Administration, 2016b). Hookah users tend to use these pipes socially at parties, cafes, and lounges (Maziak et al., 2015). Smokeless tobacco products include chewing tobacco (also known as spit tobacco), dry snuff, moist snuff or snus, and some dissolvable tobacco products. The tobacco in these products may be loose leaf, powdered, or in pouches (US Food and Drug Administration, 2016c).

While cigarettes remain the predominant form of tobacco used in the US, alternative tobacco products have become highly available in the US market, and the sales of these products have increased since 2002 (Agaku & Alpert, 2016; Delnevo et al., 2014; Marynak et al., 2017). E-cigarettes have become the most prevalent alternative tobacco, with 6.6% of all adults in the US reporting “every day,” “some days,” or “rare” e-cigarette use between 2013 and 2014; these are followed by cigars (5.4%), hookah (4.3%), and smokeless tobacco (3.5%) (Hu, 2016). Alternative tobacco use has been greatest among respondents who are male, youthful, racial/ethnic minorities, less educated, less wealthy, and sexual minorities (King, Dube, & Tynan, 2012).

Some alternative tobacco products, such as e-cigarettes and hookah, have gained popularity rapidly in recent years (Gilreath et al., 2016; King et al., 2013; Maziak et al., 2015;

Rath et al., 2012). A study using a nationally representative annual survey showed that between 2010 and 2013, ever use of e-cigarettes spiked from 1.8% (2010) to 13.0% (2013) among US adults, while current use of e-cigarettes increased from 0.3% to 6.8% (McMillen, Gottlieb, Shaefer, Winickoff, & Klein, 2015). Other products such as cigars and smokeless tobacco stayed relatively stable over the past decades (Agaku et al., 2014, SAMHSA, 2014). In general, correlates of alternative tobacco product use include being smokers, young adults (18-24 year), non-Hispanic White, and male (McMillen, Maduka, & Winickoff, 2012; Richardson et al., 2014).

Due to marketing by the tobacco industry and lack of communication about the risks of alternative tobacco use, some people, including smokers and non-smokers, have incorrect knowledge or perceptions about alternative tobacco products (Creamer et al., 2016; Latimer, Batanova, & Loukas, 2014). Many believe that alternative tobacco products have significantly lower health risks than cigarettes, can facilitate smoking reduction or cessation, or can be used where smoking is not allowed (Berg, Haardoerfer, Escoffery, Zheng, & Kegler, 2015; Choi, Fabian, Mottey, Corbett, & Forster, 2012; Etter, 2010). However, any form of tobacco use is harmful, and no empirical evidence can support the perception that alternative tobacco products can help smokers quit successfully.

Some alternative tobacco products have been known to contribute to significant health problems. For example, evidence shows that cigar use is a risk factor for coronary heart disease, lung cancer, oral cancer, and cancer of both respiratory and digestive tracts (Baker, 2000). Hookah use relates to an increased risk of respiratory disease, cardiovascular disease, periodontal diseases, oral cancer, lung cancer, low birth weight, mental health disorders, and metabolic syndrome (Akl et al., 2010; Waziry, Jawad, Ballout, Al Akel, & Akl, 2016). Similarly,

smokeless tobacco (SLT) use has been linked to oral lesions, oral and pharyngeal cancers, bladder and pancreatic cancer, and periodontal diseases (Boffetta, Hecht, Gray, Gupta, & Straif, 2008; Critchley, 2003). Moreover, use of novel alternative tobacco products is concerning because it puts nonsmokers at risk for cigarette smoking (Amrock & Weitzman, 2015; Coleman et al., 2016; Delnevo, Villanti, Wackowski, Gundersen, & Giovenco, 2016) and because it is associated with current smokers maintaining their behavior or progressing to regular use (Kalkhoran & Glantz, 2016; Popova & Ling, 2013; Wolfson et al., 2015).

Although tobacco use has been declining in general, the rates of use of more than one tobacco product—also referred to as *dual use*, *polytobacco use*, *multiple tobacco product use*, *concurrent tobacco use*, or *concomitant tobacco use* – remained relatively stable from 2002 to 2011 (Fix et al., 2014). However, consuming two or more tobacco products has become increasingly common in some subgroups of tobacco users, such as users of some product combinations, users under age 26, and female users (Backinger et al., 2008; Fix et al., 2014). Cigarette smokers are also more likely to be multiple product users, because they may use alternative tobacco products to circumvent smoking restrictions and to limit environmental tobacco smoke exposure (Lee, Hebert, et al., 2014).

According to a report from the National Adult Tobacco Survey 2012, about 10.6% of US adults use more than one tobacco product (Lee, Hebert, et al., 2014). Because different tobacco products have potentially different levels of addiction and toxicity, concurrent use may be associated with increased risk of nicotine dependence, adverse health effects, and healthcare utilization compared with exclusive use of a single tobacco product (Fix et al., 2014; Jorenby, Smith, Fiore, & Baker, 2016; Parascandola, Augustson, & Rose, 2009).

Backinger and colleagues examined the prevalence, trends and correlates of concurrent tobacco use among US adults and found that gender, age, race/ethnicity, geographic region and income were associated with concurrent use of more than one tobacco product. Among daily smokers and intermittent smokers, males, younger smokers, Non-Hispanic whites, those living in the West, and those with lower incomes were more likely to use alternative tobacco concurrently. Blue-collar workers also had increased risk for concurrent use among intermittent smokers (Backinger et al., 2008). Similarly, Nollen et al. reported that compared to exclusive cigarette smokers, concurrent users of cigarette and alternative tobacco were younger in age and were more likely to be male, racial/ethnic minorities, nondaily smokers, and menthol smokers. In addition, concurrent users had higher rates of depressive symptoms (Nollen et al., 2016). Other correlates that distinguish multiple tobacco users from exclusive tobacco users include lower educational level, substance use, other risky behaviors, never-married status, prior attempts to quit, and boredom relief motives (Fix et al., 2014; Lee, Hebert, et al., 2014; Sung, Wang, Yao, Lightwood, & Max, 2016; Wong, Haardörfer, Windle, & Berg, 2016).

In summary, although cigarettes remain the most prevalent form of adult tobacco use, in recent years, emerging tobacco use patterns have raised additional health concerns. Surveillance efforts should continue to monitor changes in alternative tobacco use and further investigate the increased health risks among smokers who also use other forms of tobacco. Psychosocial factors and concurrent tobacco use status should be considered when planning tobacco prevention and control efforts.

Importance of Young Adulthood in Tobacco Use

YOUNG ADULTHOOD AS A CRITICAL DEVELOPMENTAL PERIOD

Before adopting adult roles, young people may experience life transitions and identity exploration, as well adapting to more responsibility and less social control than they experienced during adolescence (Arnett, 2000, 2005). Young adulthood, also referred to as emerging adulthood, spans roughly from ages 18 to 25. Due to extended education and delayed marriage and parenthood in modern society, young adulthood can now last through the twenties for many people (Arnett, 2005).

Due to life changes and transitions, young adulthood is a critical period for many health risk behaviors including tobacco use (Arnett, 2000, 2005). Although most experimentation with tobacco products occurs during adolescence, initiation of tobacco use has expanded from adolescence to young adulthood (Hu, 2016). Almost all tobacco users experienced their first product before the end of young adulthood (US Department of Health and Human Services, 2012). While smoking initiation has declined among adolescents (those aged 12 to 17 years), among young adults (those aged 18 to 25 years) the number of those initiating tobacco use has increased from 600,000 in 2002 to 1 million in 2013 (SAMHSA, 2014). The data from the 2011 Legacy Young Adult Cohort Study showed that about one third of 18-34 year old people who ever used tobacco reported initiating one type of tobacco product after the age of 18 (Rath et al., 2012). In addition, the progression to regular smoking and establishment of heavy cigarette use often occurs during young adulthood (Everett et al., 1999; Rath et al., 2012). About one third of adults who had ever smoked daily began doing so between 18 and 26 years of age (US

Department of Health and Human Services, 2012), and 39% of regular users reported progressing to regular use during young adulthood (Rath et al., 2012).

Current trends of tobacco use among young adults might result in a cohort effect for prevalence of tobacco use in the future (Nelson et al., 2008). Although cigarette smoking was less prevalent among young adults with higher education level, the trends of current cigarette smoking by educational level among young adults suggest a new pattern. Compared with those at higher education level, current cigarette smoking among those with less than a high school education has declined more rapidly (Nelson et al., 2008).

Between 2000 and 2014, both the young adult population and the percentage of their enrollment in postsecondary institutions rose gradually in the US. In 2014, approximately 5.7% of the total population, i.e. over 20 million students, was enrolled in postsecondary institutions. Among these college students, about 18.9 million were between 18 and 25 years of age, which roughly represented 35.3% of young adults (Snyder et al., 2016). In addition to providing a useful index of tobacco use among young adults in the US more broadly, tobacco use among college students represents a significant public health issue in itself. The transitions into and out of college offer critical opportunities for young people to experiment and make their own decisions, which also makes them vulnerable to developing risky behaviors (USDHHS, 2012).

Evidence has shown that young adults attending college are at the utmost risk for establishing long-term smoking behaviors or other tobacco use behaviors (Caldeira et al., 2012). Approximately 1 in 3 college students report using some type of tobacco product (Sutfin et al., 2012). In the general population, the risk of tobacco use is inversely associated with educational level (Gilman et al., 2008). It is not surprising that compared to young adults who are not enrolled in college, current college students are less likely to smoke cigarettes (Green et al.,

2007; Lee, Bahreinifar, & Ling, 2014; White, Labouvie, & Papadaratsakis, 2005). However, interestingly, college students have higher odds of being light and intermittent smokers (Klein, Bernat, et al., 2013) than their non-college-attending peers. In a recent study examining smoking-related behavior among bar-going young adults in New York City, findings indicated that college students are more likely to be intermittent smokers (as opposed to daily smokers) compared to those with other education status (high school graduate, dropped out of college, and college graduate) (Guillory, Johns, Farley, & Ling, 2015).

In addition, college students tend to overestimate the prevalence of tobacco use among their peers (Cunningham & Selby, 2007; Noland et al., 2016). National data from 2014 showed that about 12% of college students reported using cigarettes, 8.6% reported using hookah, 5.6% reported using cigars/little cigars/clove cigarettes, and 5.2% reported using smokeless tobacco at least once in the past month. However, data from the same survey indicated that the perceived rates of peers' use at the same point were 77%, 69%, 61%, and 61.5% respectively (American College Health Association [ACHA], 2014). Because of overestimation, many college students accept tobacco use as the social norm on campus, which may contribute to their initiation or continued use of tobacco products (Noland et al., 2016). One study (Lee, Bahreinifar, et al., 2014) collected data from a random sample of young adult bar patrons in five cities. Results from multinomial logistic regression analyses showed that, compared to their peers, current college students have significantly higher risk of using emerging alternative tobacco products (such as hookah) and using both cigarette and non-cigarette tobacco products concurrently than exclusive cigarette smokers.

YOUNG ADULTS VULNERABILITY TO TOBACCO MARKETING

Adolescents and young adults are both vulnerable to tobacco initiation and current tobacco use, especially the use of new and emerging tobacco products. Although tobacco marketing to adolescents has been restricted by the Master Settlement Agreement (National Association of Attorneys General, 1998), young adults have become an increasingly important target of the tobacco industry (Ling & Glantz, 2004; Ling & Glantz, 2002). In recent years, the tobacco industry has invested intense efforts into attracting potential young adult tobacco users (Ling & Glantz, 2004). Innovative marketing campaigns and skillful marketing strategies have been introduced to influence smoking motivations and social environments (Gilpin, 2005; Ridner, Myers, Hahn, & Ciszewski, 2010). In addition, tobacco advertising and promotions have been launched at events or venues that appeal particularly to young adults (Gilpin, 2005; Ridner et al., 2010; Sterling et al., 2013). Some tobacco products are marketed to this population as a safer, less addictive, more socially acceptable, recreational alternative to traditional cigarettes. Exposure to tobacco advertising enhances the belief that alternative tobacco is less addictive than cigarettes and thereby promotes the uptake of emerging tobacco products among young adults (Trumbo & Kim, 2015).

Due to targeted tobacco marketing, the awareness and use of emerging tobacco products is particularly prevalent among young adults. Recent studies indicate that college-age adults are more likely than older adults to have heard about or used novel alternative tobacco products (King et al., 2013; Regan, Dube, & Arrazola, 2012). One study reported that 62%, 20%, and 64% of college-age adults have heard of snus, dissolvables, and flavored little cigars, respectively, and that college-age adults have the highest rate of awareness of these products (Regan et al., 2012).

Other research showed that the prevalence of snus use is 12% among young adults, which is nine times higher than that of older adults (Lois Biener, McCausland, Curry, & Cullen, 2011).

CHARACTERISTICS OF TOBACCO USE AMONG YOUNG ADULTS

Due to the developmental feature of young adulthood and targeted tobacco marketing, young adults are at great risk for tobacco use. Several national surveys provide data for estimation of tobacco-related behavior among young adults in the US. Although a recent CDC report suggested that the decrease of tobacco use was greatest among young adults (Jamal et al., 2015), young adults still have the highest rates of both current tobacco use and current cigarette smoking among all age groups (Center for Behavioral Health Statistics and Quality, 2015; Hu, 2016). More than one-third of young adults have used at least one tobacco product, and about 28.4% have smoked cigarettes in the past 30 days (Center for Behavioral Health Statistics and Quality, 2015; Rath et al., 2012). The importance of promoting cessation among young adult smokers was highlighted by the 2012 U. S. Surgeon General's Report (US Department of Health and Human Services, 2012).

Light and intermittent smoking among young adults

Light and intermittent cigarette smoking is a particularly prevalent smoking pattern among young adults (Lee, Peters, Adams, Milich, & Lynam, 2015; Ling, Neilands, & Glantz, 2009; Robertson et al., 2016; Villanti et al., 2015). Compared with other age groups, young adults are more likely to be light and intermittent smokers than heavier or regular smokers. Light and intermittent smoking has been reported as a long-term behavior or a transitional behavior to or from daily smoking. Roughly half of intermittent smokers are converted intermittent smokers. In a random sample of 1916 young adult bar patrons (aged 18-26) in New York City, Guillory

and colleagues (2015) found that more than half (58%) of current smokers were converted nondaily smokers who had previously been daily smokers.

Light, nondaily, occasional, and intermittent smoking have increased among young adults (Schane, Glantz, & Ling, 2009). Pierce, White, and Messer analyzed four waves of a national and state representative survey from 1991 to 2002 and reported that while smoking prevalence declined at all levels among adults aged 30 years or more during this period, very light smoking (<5 cpd) increased among young adults (18-25 years). From 2008 to 2010, among daily smokers aged 18 to 25, the percentage of light smokers who smoked 5 or less cigarettes per day increased from 24.7% to 28.6% (Substance Abuse and Mental Health Services Administration, 2012).

The prevalence of smoking among college students is surprisingly high given the strong inverse relationship between education and smoking in the general population (Gilman et al., 2008). Cigarette smoking is common among college students, and the reported prevalence of smoking at least one cigarette per month among college students ranges from 28.5% (Berg, Klatt, Thomas, Ahluwalia, & An, 2009) to 30% (Wechsler, Rigotti, Gledhill-Hoyt, & Lee, 1998). Longitudinal studies have shown that low stable cigarette consumption is the most common smoking trajectory among college students (Caldeira et al., 2012), and most light and intermittent smokers maintain a low smoking level during the college years (Caldeira et al., 2012; Levy et al., 2009).

Although some studies have indicated that light and intermittent smokers are more likely than heavier or regular smokers to be planning to quit and/or to have a higher self-efficacy for quitting (Boulos et al., 2009; Kotz, Fidler, & West, 2012), others suggested that light smokers (who smoked 1-5 cpd) are less motivated to quit (Etter, 2004), and after quitting, have relapse rates similar to those of heavy smokers (Choi, Okuyemi, Kaur, & Ahluwalia, 2004). Non-daily

smoking during young adulthood has been associated with increased odds of transitioning into regular smoking by age 38 (Robertson et al., 2016).

Social smoking and smoker identity among young adults

As addressed in previous sections, young adults represent the highest risk group for smoking, and the most common pattern of smoking among young adults is light and intermittent smoking. Due to the characteristics of young adulthood, the traditional measures of being a smoker, such as the 100 cigarettes criterion, might be inappropriate for defining smoking status among young adults (Bondy et al., 2009; Ryan et al., 2012). In addition, young adults are less likely to identify themselves as smokers, and their smoking has a strong relation to social smoking. Young adults' self-identification as nonsmokers and social smokers presents a particular challenge for smoking reduction and cessation (Song & Ling, 2011; Villanti et al., 2017; Walker & Loprinzi, 2015).

Studies have reported that over half of college smokers denied being smokers despite having smoked during the past 30 days (Berg, Lust, et al., 2009; Levinson et al., 2007). Those who are younger, male, attending 4-year colleges, alcohol consumers, and those who smoke at low frequency, on a non-daily basis, or at social events were more likely to deny being a smoker (Berg, Lust, et al., 2009; Robertson et al., 2016). They may underestimate the health risks associated with their tobacco use and overestimate their ability to quit (Levinson et al., 2007; Thompson et al., 2007). Denial of being a smoker has been associated with reporting not being addicted to cigarettes (Levinson et al., 2007), not attempting to quit smoking (Berg et al., 2009) and not accounting for adverse health consequences of smoking (Brown et al., 2011).

According to a study using a national representative college student sample, more than half of current college student smokers were social smokers. Social smoking is a distinct pattern of tobacco use and is independently related to less days of use, fewer cigarettes used per day, less nicotine dependence, less quitting intention, and fewer recent attempts to quit (Moran, Wechsler, & Rigotti, 2004).

Brown et al., (2011) conducted eight focus groups of intermittent smokers who were college students. Findings indicated that college students who smoke on a nondaily basis use smoking as a tool to socialize with others or to soothe negative emotions. Few participants identified themselves as "smokers," and few expressed a desire to quit. Although many intermittent smokers were aware of smoke-related health risks, they thought they were immune to the risks. This study highlights the need to further examine light and intermittent smokers due to their distinctive smoking motives and their denial of smoker identity.

Trajectories and transitions of tobacco use in young adulthood

A group of longitudinal studies has demonstrated the trajectories and transitions of tobacco use from adolescence to young adulthood (Chassin, Presson, Pitts, & Sherman, 2000; Costello, Dierker, Jones, & Rose, 2008; Crane, Langenecker, & Mermelstein, 2015; Dierker et al., 2012; Dutra, Glantz, Lisha, & Song, 2017; Huh, Huang, Liao, Pentz, & Chou, 2013; Huh et al., 2013; Klein, Forster, & Erickson, 2013; Lenk, Erickson, & Forster, 2017; Lenz, 2003; Mathur, Stigler, Erickson, Perry, & Forster, 2014; Mathur et al., 2014; Orlando et al., 2004; Paavola, Vartiainen, & Haukkala, 2004; Tucker, Ellickson, & Klein, 2003). Chassin and colleagues examined literature concerning trajectories of tobacco use from adolescence to young adulthood and identified 17 related studies conducted by the year 2009. In a recent cohort study,

Lenk et al. (2017) followed participants for 14 years beginning at age 12 to 16 and identified their trajectories of smoking behavior from 2000 to 2013. They utilized growth mixture modeling and found five distinct trajectories: of 4241 participants, 59.5% were classified as "nonsmoker," 14.2% were "early-onset regular smokers," 11.5% were "occasional smokers," 9.4% were "late-onset smokers," and 5.3% were "quitters." In another longitudinal study, Dutra and colleagues used 15 annual waves of smoking data (1997-2011) among 8,791 individuals aged 12 to 30. They also identified five trajectories: never users (34.1%), early-established smokers (39.0%), experimenters (13.6%), quitters (8.1%), and late escalators (5.2%).

Although these longitudinal analyses used various measures and statistical models and identified different trajectories, it is worth noting the similarities in their results. Taken together, these studies investigated the initiation, escalation, reduction, or cessation of cigarette smoking from adolescence to young adulthood. Each study demonstrated that significant portions of smokers initiated smoking or developed regular smoking patterns after the age of 18. With few exceptions, no gender differences were observed across trajectory groups. One important issue raised by describing trajectories of smoking is racial/ethnic differences. Compared with ethnic minorities, white participants were more likely to be non-daily smokers, to begin smoking earlier, or to reach regular smoking earlier (Chassin, Curran, Presson, Sherman, & Wirth, 2009; Lenk et al., 2017). Researchers focused on cigarette smoking behavior, and very few studies investigated trajectories or changes of non-cigarette tobacco products (Biener & Hargraves, 2015; Hair et al., 2017; Meier, Lechner, Miller, & Wiener, 2013).

Moreover, many longitudinal studies have raised important questions about the trajectories of tobacco use conjoined with other substance use (Huh et al., 2013; Jackson, Sher, Rose, & Kaprio, 2009; Jackson, Sher, & Schulenberg, 2005; Nelson, Van Ryzin, & Dishion,

2015). These studies highlight the comorbidity of risk behaviors including tobacco use, alcohol use and other drug use, and the significance of early-onset problem use in young adulthood.

The prevalence and timeline of transitioning into regular use is not clear. It is important to note that not every individual who initiates cigarette smoking becomes dependent on tobacco (Levy et al., 2009). Approximately one third of individuals who try cigarettes become daily smokers (US Department of Health and Human Services, 2012). However, studies have suggested that symptoms of nicotine dependence such as loss of autonomy can be experienced after only a very low level of cigarette consumption (DiFranza et al., 2007). Since light and intermittent smoking has become more prevalent among young adult cigarette smokers, more research is needed to understand their transition to light and intermittent smoking (Schane, Glantz, & Ling, 2009; Shiffman, 2009b).

The relationship between risk factors and transitioning patterns of tobacco use in young adults is still uncertain, and it is likely that multiple factors may make unique contributions to initiation and escalation of use. It is critical to understand potential predictors and associational factors related to transitions in tobacco use during the developmental period of emerging adulthood. Thus, the broad aim of this dissertation research is to examine patterns of tobacco use in order to determine the relation of individual difference variables to tobacco initiation and escalation in young adults.

Transition of light and intermittent smoking among college students

A group of studies has examined trajectories and transitions in light and intermittent smoking (Cabriales, Suro Maldonado, & Cooper, 2016; Caldeira et al., 2012; Fagan, Brook, Rubenstone, Zhang, & Brook, 2009; Levy et al., 2009; Lindström, Isacsson, & Malmö Shoulder-

Neck Study Group, 2002; McDermott, Dobson, & Owen, 2007; Wang, Sung, Yao, Lightwood, & Max, 2017; Wetter et al., 2004; White et al., 2009). In these studies, researchers followed longitudinal cohorts of smokers over time to determine whether light and intermittent smoking was a long-lasting stable status or an unstable pattern transitioning toward heavier smoking, lighter smoking, or cessation. Although most studies have followed smoking from adolescence to young adulthood, three studies have investigated the trajectories of light and intermittent smoking among college students.

Wetter et al. (2004) followed a cohort of college students and found that 87% of daily smokers and 50% of occasional smokers continued to smoke 4 years later. They also reported that occasional smokers were more likely to quit than to maintain their occasional pattern of use or transition to daily use. However, with only two waves of data, this study could not describe the stability of smoking patterns throughout the follow-up period.

White, Bray, Fleming, and Catalano (2009) followed a large cohort of high school seniors into early adulthood. They found that nonsmoking and heavy smoking status were much more stable than light smoking. More than three-quarters of heavy smokers remained heavy smokers 2 years later, but only 31% of light smokers remained light smokers.

In a trajectory analysis, Caldeira et al. (2012) examined trajectories of cigarette smoking patterns in college students over 4 years and depicted five smoking trajectories based on smoking frequency (number of smoking days). In a sample of 1253 college students, 71.5% were "stable nonsmokers," 13.3% were "low-stable smokers," 6.5% were "low-increasing smokers," 5.5% were "high-stable smokers," and 3.2% were "high-decreasing smokers." During the college years, most student smokers either maintained a similar pattern of use or increased their smoking frequency, and only 3.2% decreased their smoking frequency. The results also showed that all

smoker groups used no more than 5 cpd, and daily smoking and nicotine dependence were rare among college students (Caldeira et al., 2012).

Alternative tobacco use among young adults

Data from national surveys showed that use of alternative tobacco, especially emerging types such as hookah and e-cigarettes, is higher among young adults than among other age groups (Hu, 2016). Compared with other age groups, young adults are more likely to use alternative tobacco on a non-daily basis, to report a lower level of consumption and to use alternative tobacco products at social events (Curry, Sporer, Pugach, Campbell, & Emery, 2007; Hammond, 2005; Hu, 2016; Song & Ling, 2011). In addition, most young adult users of multiple tobacco products smoke cigarettes concurrently (Soneji et al., 2016) and young adults have the highest rate of multiple tobacco use compared with other adult age groups (Lee, Hebert, et al., 2014).

The prevalence and trends of alternative tobacco use have been explored among young adults. According to the results from the 2014 National Survey on Drug Use and Health, 9.7% of young adults aged 18 to 25 were current cigar smokers, 5.6% were current smokeless tobacco users, and 1.9 % were current pipe tobacco users. The percentage of young adults in 2014 who were current cigar smokers was lower than in the 2002-2012 period. In contrast, trends of current users of smokeless tobacco or pipe tobacco were relatively stable from 2002 to 2014. A report from the NHIS 2014 showed that in 2014, 21.6% of young adults (18-24) had tried e-cigarettes, and 5.1% of young adults were current users (Schoenborn & Gindi, 2015). A study using a nationally representative annual survey data showed that between 2010 and 2013, ever use of e-cigarettes increased dramatically from about 0 (2010) to 14.2% (2013) among US adults, while

current use of e-cigarettes increased from 0.3% to 6.8% (McMillen, Gottlieb, Shaefer, Winickoff, & Klein, 2015).

Previous studies have also explored the prevalence of alternative tobacco use among college students. According to a report of ACHA-NCHA IIc, in 2015, 16.6% of undergraduate students had tried e-cigarettes, and 5.4% of undergraduate students were current electronic cigarette users. Past research suggests that among US college students, the prevalence of ever hookah use is 20%–40%, and the prevalence of current/ past 30 day hookah use is 5%–15% (Gathuru, Tarter, & Klein-Fedyshin, 2015; Grekin & Ayna, 2012; Heinz et al., 2013; Primack et al., 2013; Shepardson & Hustad, 2016; E. L. Sutfin et al., 2013).

Many young adults who smoke cigarettes also are concurrent users of alternative tobacco products including cigars, hookahs and smokeless tobacco (Enofe, Berg, & Nehl, 2014). However, limited research has explored trends of alternative tobacco use among current smokers: that is, the dual use of cigarette and alternative tobacco products. Little is known about whether these trends are different for smokers who vary their cigarette consumption (Bonnie, Stratton, & Kwan, 2015; Ramo, Liu, & Prochaska, 2012; Rath et al., 2012; Richardson, Williams, Rath, Villanti, & Vallone, 2014).

About half of US young adult tobacco users were poly tobacco users; that is, they use more than one type of product concurrently (Kasza et al., 2017; Soneji et al., 2016). Use of alternative tobacco products is a gateway to both concurrent and subsequent use of other tobacco products, including traditional cigarette smoking (E. M. Meier, Tackett, Miller, Grant, & Wagener, 2015; Sutfin et al., 2012), and is likely to increase the risk of nicotine dependence.

Soneji and colleagues (2015) conducted a two-wave national longitudinal study among youth and young adults (aged 15 to 23) and assessed whether hookah use and smokeless tobacco

use among never smokers are risk factors for subsequent cigarette smoking. They reported that hookah use and snus use at baseline are independently associated with the onset of cigarette smoking, current cigarette smoking, and higher intensity of cigarette smoking at follow-up.

Delnevo and colleagues (2016) selected a sample of lifetime smokers (aged 18-34) from those who had reported their current cigarette use as well as their smoking behavior one year prior to the study. These researchers examined self-reported changes in smoking behavior over the course of the year and the potential influence of alternative tobacco products on these changes. The results showed that most young adults (73.1%) reported maintaining current smoking status, while 8.2% reported having quit, 5.8% reported that they decreased smoking, 5% progressed from someday to daily smoking and 8% increased from non-current to current smoking. They also found that alternative tobacco use was not associated with increasing smoking but was negatively associated with remaining non-smoking (Delnevo, Villanti, et al., 2016).

Dunbar and colleagues examined how alternative tobacco use and reasons for use correlate with cigarette consumption patterns and nicotine dependence among daily and intermittent smokers. Results showed that compared to daily smokers, intermittent smokers were more likely to use combustible alternative tobacco products and less likely to endorse reducing smoking as a reason to use alternative tobacco products. Moreover, alternative tobacco product use in intermittent smokers was associated with higher nicotine dependence (Dunbar, Shadel, Tucker, & Edelen, 2016).

Some studies have investigated the role of alternative tobacco use on cigarette smoking among college students. Sutfin et al. (2015) conducted a six-wave longitudinal study among college students from 11 four-year universities in North Carolina and Virginia through their

college years. Using multivariable mixed-effects logistic regression analysis, they found that trying e-cigarettes after enrolling in college was a significant predictor of cigarette smoking by the end of a student's college years. Using the same data source and similar methods of data analysis, Wolfson et al. (2015) reported that dual users of cigarette and smokeless tobacco are more likely to be current smokers in their senior year than those who use cigarettes only, although this difference was not statistically significant.

In summary, young adults have relatively high rates of both current tobacco use and current cigarette smoking compared to other age groups. Few studies have examined the trends of tobacco use among young adults, and even fewer have related trends of tobacco use to different subgroups of young adults. Light and intermittent smoking in young adulthood is particularly important because it is a transitional behavior in a critical period of human development. Although previous studies have begun to explore the impact of alternative tobacco use on smoking trajectories, this impact remains poorly understood. Results from limited prior research have suggested that alternative tobacco product use may increase subsequent cigarette use. If use of alternative tobacco products is accompanied by progression to regular use, the current generation of young adults may carry future burdens from health consequences of alternative tobacco use. Much work is still needed to help inform the public and promote effective health planning.

DETERMINANTS OF TOBACCO USE AMONG YOUNG ADULTS

The patterns and trajectories of smoking behavior among young adults are determined by different factors, including individual and contextual factors. Some of the factors may put young adults at higher risk for cigarette smoking or multiple tobacco use, while others may buffer the

impact of risk factors, therefore decreasing the possibility of initiation or facilitating cessation. As addressed previously, young adults are going through a critical transition period from adolescence to young adulthood. The risk and protective factors experienced in this period may have long-term effects on behavioral, physical or psychological outcomes later in their lives. It is particularly important to identify the main variables that can discourage college students from tobacco use.

Factors affecting tobacco use among young adults

Determinants of light and intermittent smoking among young adults

Light and intermittent smoking differs from other patterns of smoking among young adults with regard to gender, age, race/ethnicity, socioeconomic status, college status, smoker identity, age of smoking initiation, reasons to smoke (such as smoking for social reasons), previous quit attempts, attitudes toward cigarettes, responses to situational factors (such as environmental cues and stimuli), nicotine dependence, and depression (Coggins et al., 2009; Darlow & Lobel, 2012; Klein, Bernat, et al., 2013; Reyes-Guzman et al., 2017; Shiffman et al., 2014; Thrul et al., 2016).

In both population-based studies and systematic reviews, compared to heavier or daily smokers, light intermittent smokers were more likely to be young adults, higher educated, of higher socioeconomic status, less nicotine dependent, more likely to plan to quit in the next year, demonstrate a social smoking pattern, and initiate smoking at an older age (Coggins et al., 2009; Levy et al., 2009). However, few studies have examined whether smoking behavior differs among subgroups of young adults.

Using data pooled from three population-based surveys, Reyes-Guzman et al. (2017) confirmed the determinants of light and intermittent smoking reported by previous studies including early initiation as a major risk factor for regular smoking in late adolescence and young adulthood. However, they also found that although African Americans exhibited high rates of early smoking onset, in comparison with Whites and Hispanics, fewer African Americans made the transition to regular smoking. In addition, this study also suggested that light and intermittent smoking behavior is more likely to be influenced by concurrent alternative tobacco use. Trinidad et al. (2009) analyzed nationally representative data and showed that in comparison with non-Hispanic Whites, ethnic minorities, especially Hispanic smokers, were more likely to be intermittent smokers.

There is conflicting evidence with regards to smoking behavior in relation to gender. Although some studies indicated no significant gender difference in light and intermittent smoking, other studies showed that light and intermittent smokers are more likely to be women (Enofe et al., 2014)(Ackerson & Viswanath, 2009; Trinidad et al., 2009). Using data from the 2011 National Survey on Drug Use and Health, Li et al. (2015) examined the differences between young adult women who are very light smokers (1-5 cpd) and similar women who are at other smoking levels. Among young adult women, very light smokers were more likely than other smokers to recognize high risks in smoking, less likely to report nicotine dependence, and more likely to be nondaily smokers.

Determinants of alternative tobacco use among young adults

Limited research has documented the psychosocial characteristics associated with using different tobacco products. McMillen and colleagues claimed to be the first to examine the

determinants of four emerging alternative products, including snus, hookah, dissolvable tobacco and e-cigarettes, using national representative data. They found that smoking status, gender, age group, and educational attainment were associated with taking up at least one emerging tobacco product. Compared to other smokers, nondaily smokers are the most likely to have tried emerging tobacco products. Male, young adults aged 18-24 and those with college degrees and some college attainment were more likely to have tried emerging tobacco products than their counterparts (McMillen et al., 2012). Enofe and colleagues (2014) confirmed these findings among college students and found that younger, male cigarette smokers were at higher risk of alternative tobacco use. In addition, they also reported that intermittent smokers who have never been daily smokers were more likely to use alternative tobacco products than former daily smokers.

Although findings are inconsistent across studies, racial/ethnic minorities may be more likely to use alternative tobacco than Whites. Analysis of the National Health Interview Survey 2014 showed that current e-cigarette use was higher among non-Hispanic American Indian or Alaska Native (AIAN) adults and non- Hispanic white adults than among Hispanic, non-Hispanic black, and non-Hispanic Asian adults (Schoenborn & Gindi, 2015).

Other determinants of using alternative tobacco include being marijuana users, having more friends that smoke, living with a smoker, exhibiting less negative attitudes toward smoking, more serious depressive symptoms, higher sensation seeking scores and more frequent alcohol consumption _. In addition to investigating the determinants of alternative tobacco product use, research also has begun to depict the profile of poly users who use both cigarettes and alternative tobacco product concurrently (Nollen et al., 2016; Soneji et al., 2016). Males, binge alcohol drinkers, marijuana users, college students with greater acceptance of cigarette smoking and

indicators of nicotine dependence were more likely to be poly tobacco users (Butler, Ickes, Rayens, Wiggins, & Hahn, 2016; Loukas et al., 2016; Wong, Haardörfer, Windle, & Berg, 2016; Yu, Saddleson, Murphy, Giovino, & Mahoney, 2017).

In summary, young adults' current tobacco use and trajectories are complex. Although socio-demographic and psychosocial factors associated with tobacco use have been examined by previous research, determinants of tobacco use among young adults were not fully explored. More research is needed to understand the transitional processes of light and intermittent smoking and the role of alternative tobacco products in smoking transitions in young adults.

CHAPTER THREE (STUDY 1): TRENDS OF VERY LIGHT SMOKING AND OTHER TOBACCO USE PATTERNS AMONG YOUNG ADULTS

Introduction

While smoking has declined over the past two decades (Jamal et al., 2015), tobacco use among young adults remains a serious public health concern in the United States. Young adults have the highest rates of tobacco use among all age groups, with more than one-third having used tobacco in the past 30 days (Substance Abuse and Mental Health Services Administration [SAMHSA], 2014). Although tobacco use trends (including traditional cigarette and alternative tobacco products) have been widely examined in the general population and among adolescents (Centers for Disease Control and Prevention, 2016b; Creamer, Perry, Harrell, & Diamond, 2015; McMillen et al., 2015; Schauer, Malarcher, & Mowery, 2016; Singh et al., 2016), the trends of popular tobacco use patterns (i.e., very light smoking and alternative tobacco use) among young adults have not been fully explored. The purpose of this study is to describe the trends in very light smoking (1-5 cpd) among young adults (18-25 years) in the United States and to examine the socio-demographic (e.g. sex, race/ethnicity, age group, education level, and education status) and behavioral determinants (i.e, daily smoking status and use of alternative tobacco products (ATPs)) of these trends.

Young adulthood (Arnett, 2005; Arnett, 2000) is a critical developmental period for engaging in many health-related behaviors, including initiating and maintaining cigarette smoking (Caldeira et al., 2012) and progressing to regular tobacco use (Cooke et al., 2016; Loukas, Batanova, Fernandez, & Agarwal, 2015; Rath et al., 2012). Unfortunately, these

developmental features have been strategically used by the tobacco industry to attract young adults, making this group a vulnerable population for tobacco use, especially for the use of new and emerging tobacco products (Gilpin, 2005; Ling & Glantz, 2002, 2004; Ridner et al., 2010). Initiation of tobacco use has expanded from adolescence to young adulthood (Hu, 2016). According to national representative annual data, while smoking initiation declined among adolescents (aged 12 to 17) tobacco initiation has increased from 2002 to 2013 among young adults (aged 18 to 25 years) (SAMHSA, 2014). Data from the 2011 Legacy Young Adult Cohort Study showed that 32 percent of tobacco users began using tobacco products after the age of 18 and 39 percent of regular users began regular use between the ages of 18 and 34 (Rath et al., 2012). Data from the national Population Assessment of Tobacco and Health Study (PATH) and two Texas cohort studies showed that compared with youth aged 11 to 17 years, young adults aged 18 to 24 years had significantly higher incidence rates than youth to initiate ever and current use of each/all tobacco products (Perry et al., 2018).

In recent years, very light smoking (≤ 5 cigarettes per day [cpd]) has become the predominant form of tobacco use among young adults aged 18-25 (Pierce, White, & Messer, 2009; Schane, Glantz, & Ling, 2009; SAMHSA, 2012). Using a national representative survey, Pierce, White and Messer (2009) reported that from 1992 to 2002, very light smoking (1-4 cpd) increased significantly among young adults aged 18-25 and was particularly prevalent among college students. Focusing on trends of cigarette use among adolescents and young adults from 2004 to 2010, a NSDUH report showed that although prevalence of past month smoking and daily smoking decreased from 2004 to 2010, the percentage of very light smoking increased among daily smokers aged 18-25 (Substance Abuse and Mental Health Services Administration, 2012).

Previous research examined trends of cigarette smoking among different subgroups. For example, Nelson and colleagues (2008) described the overall and subgroup trends of smoking among young adults using data from the National Health Interview Survey from 1974 to 2005. Subgroup analyses among young adults included age group (18-19 vs 20-24), sex, race/ethnicity, education level, geographic region, and population density. In general, smoking declined across all subgroups. However, trends of current smoking differed by race/ethnicity and education level. The decline of smoking prevalence was much faster among Hispanics and Blacks than among White young adults. Although cigarette smoking was more prevalent among young adults with lower education level compared with those with higher educational levels, current cigarette smoking among those with less than a high school education has declined more rapidly. Jones et al (2011) examined gender and racial/ethnic differences in trends of three smoking patterns, i.e. light smoking ($\leq$ 5 cpd), moderate smoking (6-10 cpd) and heavy smoking ($\geq$ 11 cpd), among high school students in the US. By analyzing data from the 1991 – 2009 national Youth Risk Behavior Surveys (YRBS), increasing trends of light smoking were found among white students and across gender groups but not among Hispanic and Black students. Among Hispanic and Black students, light smoking remained stable. The subgroup differences in trends of very light smoking have not been thoroughly examined among young adults.

Historical analyses of tobacco use trends have shown changes in alternative tobacco products (ATP) use over time. According to data from recent national surveys, some ATPs such as e-cigarettes and hookah have gained popularity rapidly among young adults (Gilreath et al., 2016; King et al., 2013; Maziak et al., 2015; Rath et al., 2012), and the use of ATPs, especially emerging types such as hookah and e-cigarettes, is higher among young adults than among other age groups (Hu, 2016). One study examined mixed use of different tobacco products among a

nationally representative sample over ten years and suggested that concurrent use of more than one product is increasingly prevalent among young adults (Fix et al., 2014).

Limited research has explored trends of alternative tobacco use among light, moderate and heavy smokers in adolescents (Nasim, Khader, Blank, Cobb, & Eissenberg, 2012). However, the trends of ATP use among young adults have not been fully explored. Although very light smoking reflects a pattern of smoking in social situations (Schane et al., 2009; Waters, Harris, Hall, Nazir, & Waigandt, 2006) and has been associated with increased susceptibility to ATP use (e.g., smokeless tobacco, cigar and hookah) (Li, Loukas, & Perry, 2018), trends of ATP use among different young adult smoking subgroups in the past decade have not been fully examined. (Nelson et al., 2008; Substance Abuse and Mental Health Services Administration, 2012). Little is known about whether the trends of ATP use differ for young adults smokers who vary in cigarette consumption (Bonnie et al., 2015; Ramo et al., 2012; Rath et al., 2012; Richardson, Williams, et al., 2014).

Due to the limitations of prior studies, there continues to be a need for further investigation of trends of smoking status among young adults. The purpose of this study is to determine the trends in very light smoking (1-5 cpd) among young adults (18-25 years) in the United States, using repeated cross-sectional nationally representative data from the National Survey of Drug Use and Health, 2002 – 2015. Trend analyses of very light smoking were first conducted on all young adults; then analyses were conducted on a subset of young adults who reported that they have ever used cigarettes and then on a subset of young adults who responded that they currently use cigarettes. To examine differences in subgroups, trends of very light smoking were investigated by key socio-demographic factors (i.e., sex, race/ethnicity, educational status, and age

group), behavioral determinants (e.g., smoking history and daily smoking status), and use of ATPs (cigars, hookah pipe, and smokeless tobacco).

Research Questions

1) What was the change in the prevalence of current very light smoking among young adults over time from 2002-2015?
2) How did trends of current very light smoking vary by sex, race/ethnicity, age group or educational status from 2002-2015?
3) How did trends of very light smoking among young adults vary by smoking history and daily smoking from 2002-2015?
4) How did trends of very light smoking vary related to concurrent use of any alternative tobacco product (ATP) from 2002-2015?
5) What was the change in the prevalence of ATP use among all young adults over time from 2002-2015?
6) How did trends of ATP use among young adults vary by different smoking patterns from 2002-2015?

Methods

PARTICIPANTS

The author obtained data from the National Survey of Drug Use and Health (NSDUH) from 2002 to 2015. The weighted interview response rates averaged from 69.7% to 79.0% during the study period. Data for this study were drawn from approximately 536, 392 adults aged 18 or older who participated in the 2002 to 2015 NSDUH. The author has also considered using other national surveys, particularly federal tobacco-specific adult surveys such as National Health Interview Survey, the Current Population Survey, and the National Health and Nutrition

Examination Survey. The National Survey of Drug Use and Health was finally selected because of its general consistency in design and methods, length of time during which surveys were administered, sample size, and frequency of administration. The NSDUH is a nationally representative survey sponsored by the Substance Abuse and Mental Health Service Administration (SAMHSA). The purpose of this repeated cross-sectional survey is to provide national and state-level estimates on the use of tobacco products, alcohol, illicit drugs (including non-medical use of prescription drugs) and mental health among members of households aged 12 and older in the United States. One limitation of the NSDUH is that this survey did not collect data on e-cigarette use.

PROCEDURE

The NSDUH was first conducted by the US Government in 1971 and has been revised over the years. For instance, data were collected by paper-and-pencil interview (PAPI) before 1998. In 1999 the survey underwent two important design changes: 1) shifting from PAPI to the use of computer-assisted interviewing (CAI), in which most of the questions are administered through audio computer-assisted self-interviewing (ACASI); and 2) including samples in all 50 states and the District of Columbia. After 2002, the name of the survey changed from the National Household Survey on Drug Abuse (NHSDA) to the NSDUH, and a n. Since 2002, the design and methods of the survey, especially the tobacco use questions, have been generally consistent over time. Due to unequal selection probabilities at multiple stages of sample selection and various adjustments, the individual-level weight (ANALWT_C) representing an estimate of the total number of people in the target population, and two nesting variables (VESTR, VEREP) capturing the explicit stratification and clustering will be used to adjust NSDUH data to the US population aged 12 and over. The survey weights for 2011 and later are calibrated to the 2010

census while prior years are calibrated to the 2000 census. The time trend variable created and used in the analyses was a continuous variable that ranged from 0 (survey year 2002) to 13 (survey year 2015).

MEASURES

Demographics

Sociodemographic variables included sex (male, female); age group (18–20 years, 21-25); ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other ethnicities); educational level (less than high school graduate, high school graduate, some college, college graduate); and educational status (enrolled in college, not enrolled in college).

Cigarette Smoking

Ever smoker was defined as people who have ever smoked part or all of a cigarette. Current smoker was defined as people who have smoked within the past 30 days. The question used to define smoking status was: "On the one day/days when you smoked a cigarette during the past 30 days, how many cigarettes did you smoke per day, on average?" Based on responses to the smoking status question, two categories of smoking status were used: very light smokers and heavier smokers. Very light smokers were defined as those who are current smokers and smoked 5 cpd or fewer within the past 30 days; and heavier smokers were defined as those who smoked more than 5 cpd within the past 30 days.

Daily versus nondaily smoking was assessed by an item that asked respondents: "During the past 30 days, on how many days did you smoke part or all of a cigarette?" Nondaily smokers were those who smoked 1 to 29 days in the past 30 days (reference group), and daily smokers were those who smoked every day of the past 30 days. A question "Has there ever been a period

in your life when you smoked cigarettes every day for at least 30 days?" was used in this study to determine smoking history. A question asking the age when participants first smoked a cigarette was used to determine their age at smoking initiation and responses to that question were grouped into cigarette initiation before age 18 and initiation at age 18 and above.

Alternative Tobacco Use

The term "alternative tobacco product" in this study refers to cigars, hookah, and smokeless tobacco (snuff or chewing tobacco). Alternative tobacco use variables were assessed in terms of use during the 30 days prior to the survey interview. Participants were categorized into current cigar users (smoked cigars within the past 30 days); hookah pipe users (used pipe within the past 30 days); smokeless tobacco users (used snuff or chewing tobacco within the past 30 days); and alternative tobacco users (used any of the three alternative tobacco product types ≥ 1 day during the past 30 days).

DATA ANALYSIS

To account for the complex survey design of NSDUH, all data used in current analysis were weighted as well as adjusted based on stratification and clustering. The linear trend tests were conducted using SAS survey sampling and analysis procedures (SAS Institute Inc., 2015). Estimates were weighted to the national census-based population data (Fix et al., 2014; Nelson et al., 2008; Schauer, Berg, Kegler, Donovan, & Windle, 2015).

Descriptive analyses were conducted by PROC SURVEYFREQ procedure to estimate the weighted prevalence and standard error of very light smoking and alternative tobacco use in the entire sample and among subgroup of US young adults from 2002 to 2015. Subgroups

include sex, race/ethnicity, age group (18–20 vs 21–25 years), education level, and education status.

Trend analyses of very light smoking were first conducted on all young adults; then analyses were conducted on a subset of young adults who reported that they have ever used cigarettes and then on a subset of young adults who responded that they currently use cigarettes. Additional analyses investigated trends of very light smoking based on smoking history, current daily smoking status, and concurrent alternative tobacco use. Trend analyses of any alternative tobacco products use were also conducted among all young adults and among current smokers. Trends of alternative tobacco product use were then stratified by smoking status, i.e. very light smoker and heavier smoker.

We could not hypothesize a specific shape to the total population or subgroups over the periods covered, but we examined whether trends followed a linear or a polynomial model (e.g., quadratic, cubic). The analysis plan was adapted from the three-step trend analysis developed by the Youth Risk Behavior Surveillance System (YRBSS) (Centers for Disease Control and Prevention, 2016a). First, the linear and non-linear time trends were tested using logistic regression analyses with time variables controlled for sex, race/ethnicity, age group, education level, education status and behavior determinants. The SAS procedure PROC SURVEYLOGISTIC (SAS, 2009; SAS Institute Inc., 2015) with orthogonal polynomial time variables was used to assess weighted linear, quadratic or higher order significance (Clarke, Black, Stussman, Barnes, & Nahin, 2015; Schauer et al., 2015). Orthogonal coefficients were calculated using PROC IML in SAS. Linear trends test whether there are significant linear increases or decreases over time, whereas quadratic and cubic trends would suggest significant non-linear changes over time.

If only linear trends were significant, the author compared linear trends across subpopulations by including subpopulation interactions with the linear time variable (i.e., sex × time, age group × time, race/ethnicity × time, education level × time, and education status × time) (McIntire, Macy, Seo, Nelson, & Kolbe, 2014). When quadratic or cubic changes were detected, the author used SAS PROC SURVEYFREQ procedure to calculate the adjusted prevalence and standard error by year, and then export these values into Joinpoint software (4.5.0.1) to determine where the non-linear trends change (Centers for Disease Control and Prevention, 2016a; Kim, Fay, Feuer, & Midthune, 2000). Trends of prevalence were fit using joint log-linear segments, permutation tests were used to select the optimal models, and annual percent change (APC) were used to characterize trends for each segment. Within a segment, the prevalence was assumed to change at an estimated percentage of the prevalence of the previous year (Statistical Research and Applications Branch, 2017).

Results

STUDY POPULATION CHARACTERISTICS

The average annual sample of young adult respondents aged 18-25 years was 17,828, representing the young adult population of 33,358,047. Approximately half (49.7%) of the average annual sample were female and 39.1% were younger (aged 18-20 year). The majority was Non-Hispanic white (59.4%), followed by Hispanic (19.1%), African American (13.9%), and other (7.6%). Approximately 39.7% met criteria for currently enrolled college students. Approximately 18% did not complete high school, 34.3% completed high school, 34.0% had some college education and 13.7% had beyond college education. Overall, 40.8% of all participants from 2002

to 2015 reported currently using at least one tobacco product with a quarter of the sample using cigarettes exclusively, a tenth of the sample using both cigarette and an alternative tobacco product concurrently and 5.8% currently use alternative tobacco exclusively (data not shown in tables). See Table 3.1 for year-by-year demographic distribution and see Table 3.2 for year-by-year tobacco use distribution in the study sample.

TRENDS IN VERY LIGHT SMOKING

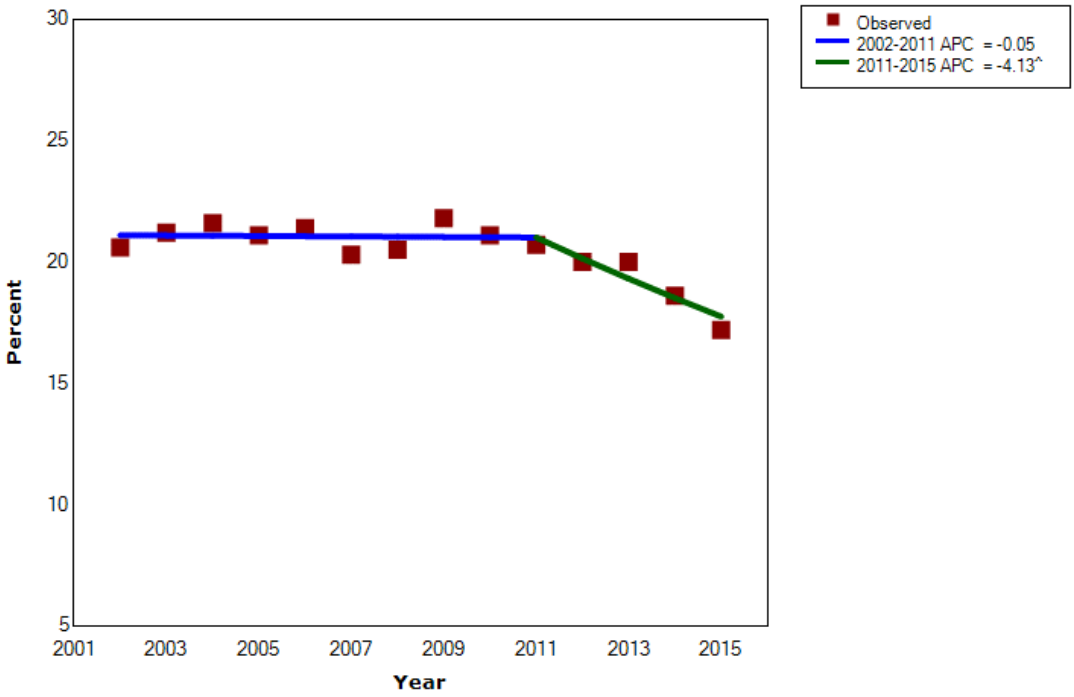
A summary of the trend analyses of very light smoking is shown in Table 3.3. Nonlinear trends were detected for very light smoking among all young adults and among ever smokers. Table 3.4, Table 3.5, and Table 3.6 present the prevalence and standard errors of very light smoking by demographic factors over a one-year interval from 2002 to 2015. Prevalence and standard error by year were examined in Joinpoint software to determine the critical "joinpoints" and to test the linearity of the resulting line segments between 2002 and 2015. Linear trends were detected for very light smoking among young adults who smoked cigarettes during the past 30 days from 2002 to 2015. Linear trends were compared across subpopulations by including subpopulation interactions with the linear time variable (i.e., sex × time, age group × time, race/ethnicity × time, education level × time, education status × time), daily smoking status × time and concurrent ATP use × time (McIntire et al. 2014).

VERY LIGHT SMOKING AMONG ALL YOUNG ADULTS

Among young adults aged 18 years to 25 years, there was a significant cubic change of very light smoking from 20.6% in 2002 to 17.2% in 2015 ($p = 0.01$) (Table 3.3 and Table 3.4). Joinpoint analyses of current very light smoking trends among all young adults are pictorially

represented in Figure 3.1. Between 2002 and 2011 the prevalence of very light smoking remained stable, then decreased significantly from 20.7% in 2011 to 17.2% in 2015 (Annual Percent Change (APC) = -4.13, $p<.05$). The estimated prevalence of very light smoking in 2012 can be calculated by (prevalence in 2011) * (100% - 4.13%), i.e. 20.7% * 0.96 = 19.9%. Joinpoint trends analyses of very light smoking by subpopulation are shown in Figures 3.2 – 3.6. From 2011 to 2015, the prevalence of very light smoking decreased significantly among most demographic subpopulations. However, the trends of very light smoking did not change significantly among young adults aged 21 to 25 (see Figure 3.2), non-Hispanic Black (see Figure 3.5), and those who have less than high school (see Figure 3.6). See Table 3.4 for prevalence and standard error of very light smoking by sex, age group, race/ethnicity, educational level, and educational status among all young adults.

Figure 3.1: Trends of very light smoking among all young adults.



Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

Figure 3.2: Trends of very light smoking by sex (male vs female) among all young adults.

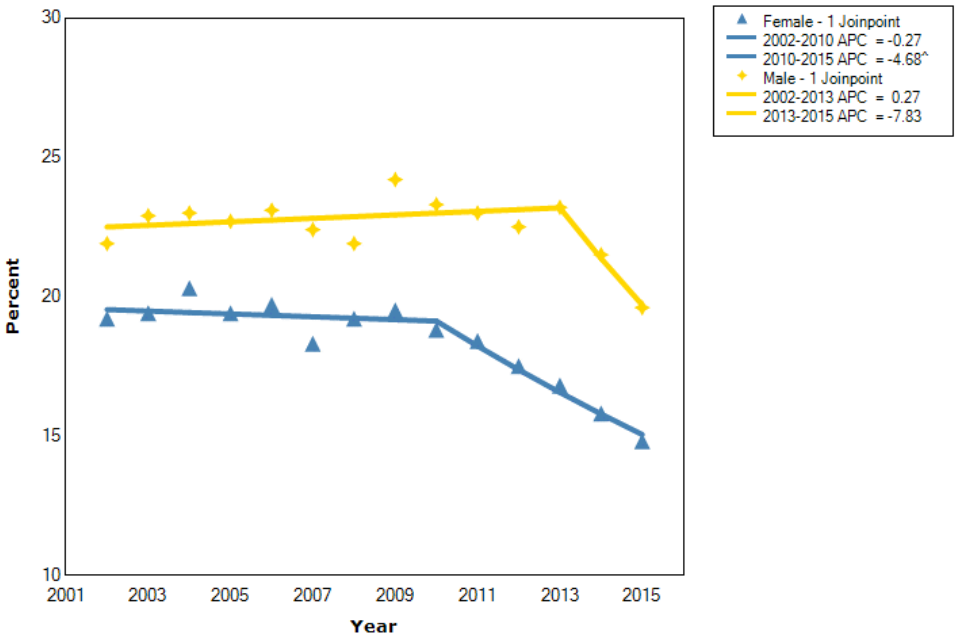
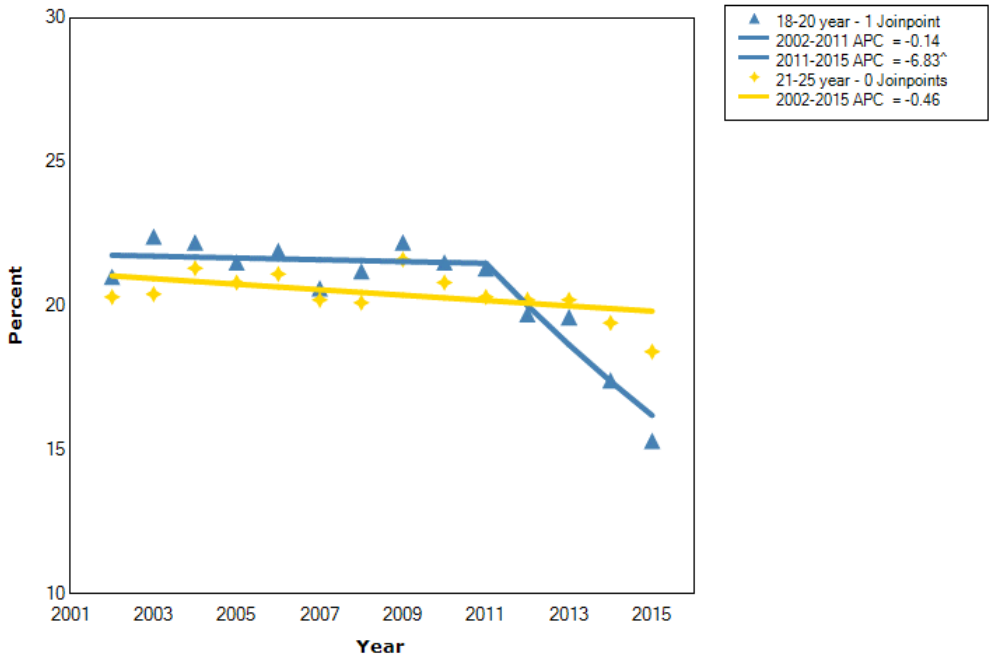


Figure 3.3: Trends of very light smoking by age groups (younger 18-20 years vs older 21-25 years) among all young adults.



Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

Figure 3.4: Trends of very light smoking by race/ethnicity among all young adults.

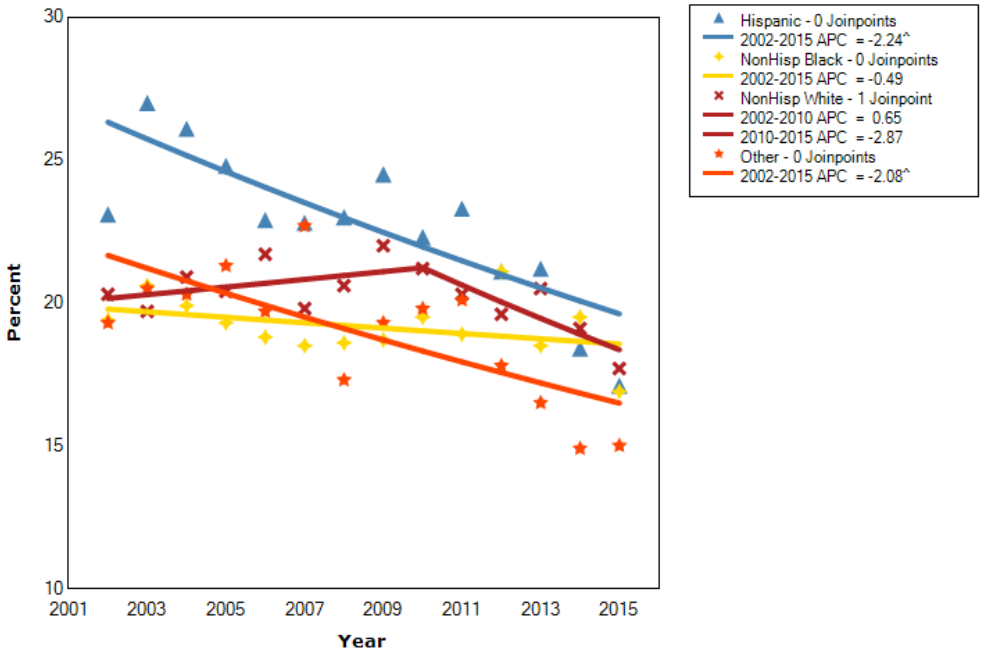
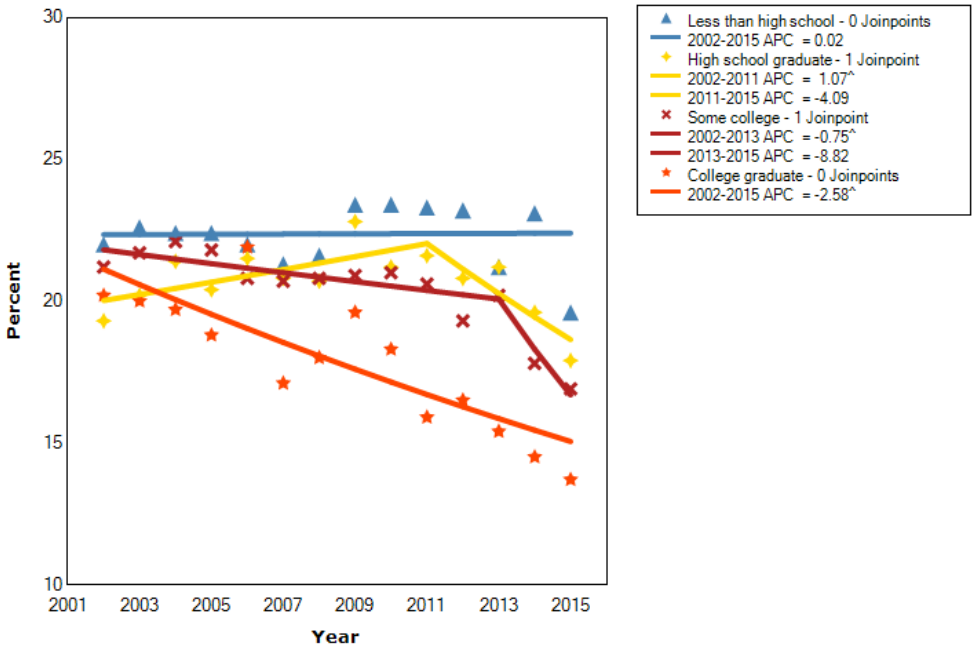
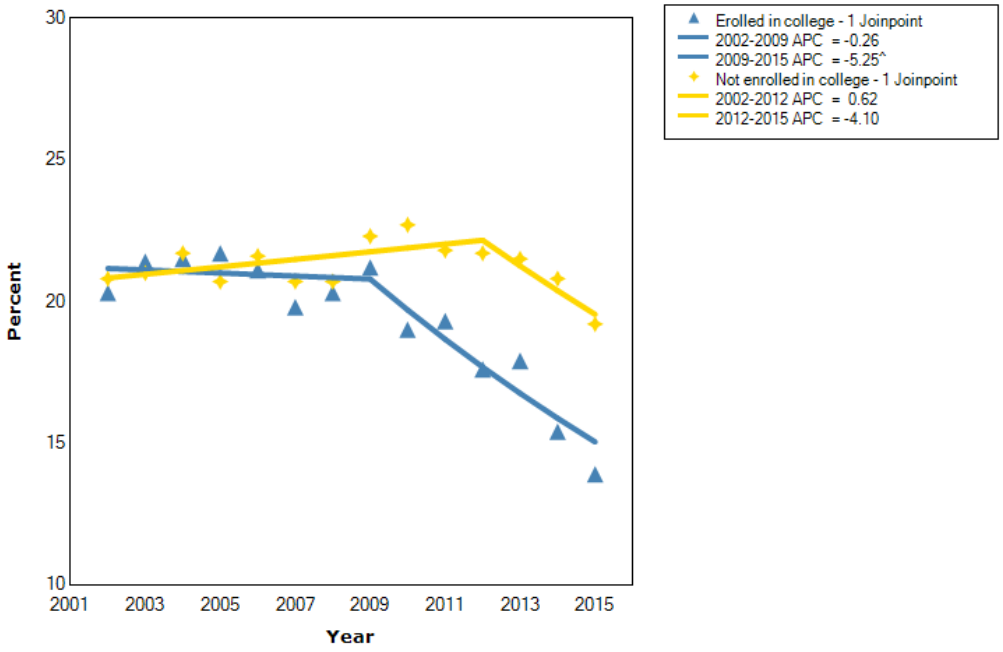


Figure 3.5: Trends of very light smoking by educational level among all young adults.



Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

Figure 3.6: Trends of very light smoking by educational status (enrolled vs not enrolled) among all young adults.



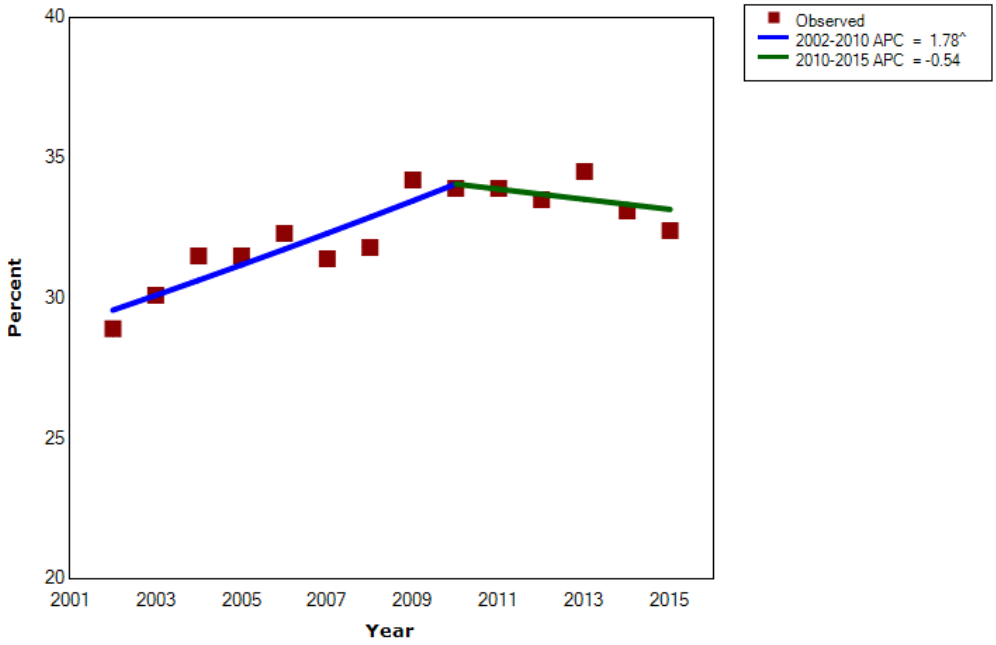
Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

VERY LIGHT SMOKING AMONG EVER SMOKERS

Among ever smokers aged 18 years to 25 years, the prevalence of very light smoking was represented by a quadratic trend from 28.9% in 2002 to 32.4% in 2015 ($p < 0.01$) (see Table 3.3). Joinpoint analyses of current very light smoking trends among ever smokers aged 18-25 are displayed in Figure 3.7. Between 2002 and 2010, the prevalence of very light smoking increased from 28.9% to 33.9% (APC = 1.78, $p <.05$, see Table 3.5 and Figure 3.7), then did not change significantly from 2010 to 2015. Joinpoint trends analyses of very light smoking among ever smokers by demographics, cigarette initiation age, and smoking history are presented in Figures 3.8 – 3.14. Over the study period, the prevalence of very light smoking increased significantly among most ever smoker subpopulations (see Table 3.5, Figure 3.8 – 3.14). However, in some

subpopulations of ever smokers, for example, Hispanic and other racial/ethnic groups (see Figure 3.10), college graduates (see Figure 3.11), and enrolled college students (see Figure 3.12), the trends of very light smoking remained stable in general. The prevalence decreased among those who initiated cigarettes after 18-years old from 35.7% in 2004 to 32.8% in 2015 (APC = -0.89, $p < .05$, see Table 3.5 and Figure 3.13). Moreover, the prevalence of very light smoking started to show decreasing trends in recent years among young adult ever smokers who were female (see Figure 3.8), aged 18-20 (see Figure 3.9), graduated from high school, had some college education (see Figure 3.11), and those who had never been daily smokers (see Figure 3.14).

Figure 3.7: Trends of very light smoking among young adult ever smokers.



Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

Figure 3.8: Trends of very light smoking by sex (male vs female) among young adult ever smokers.

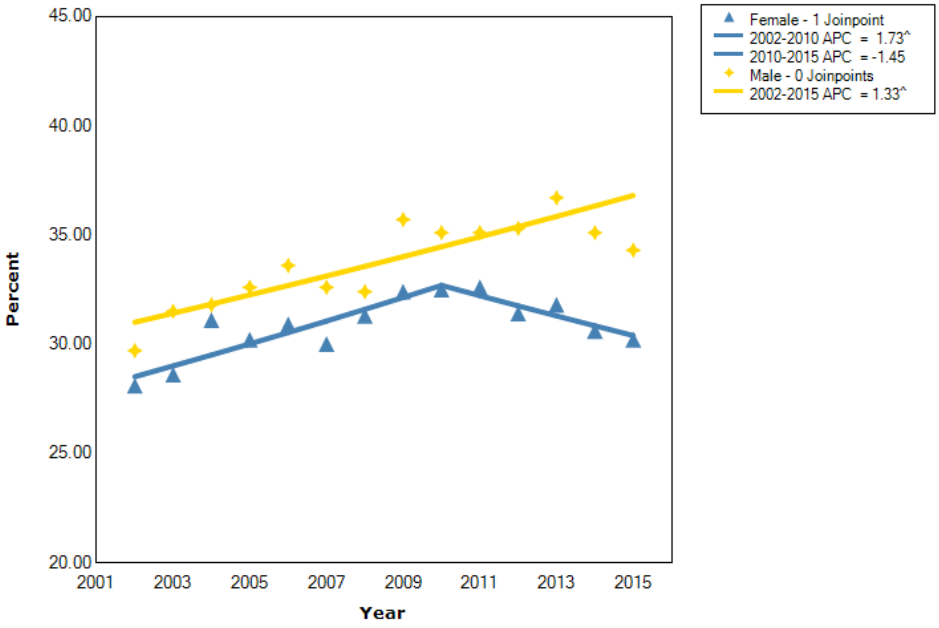
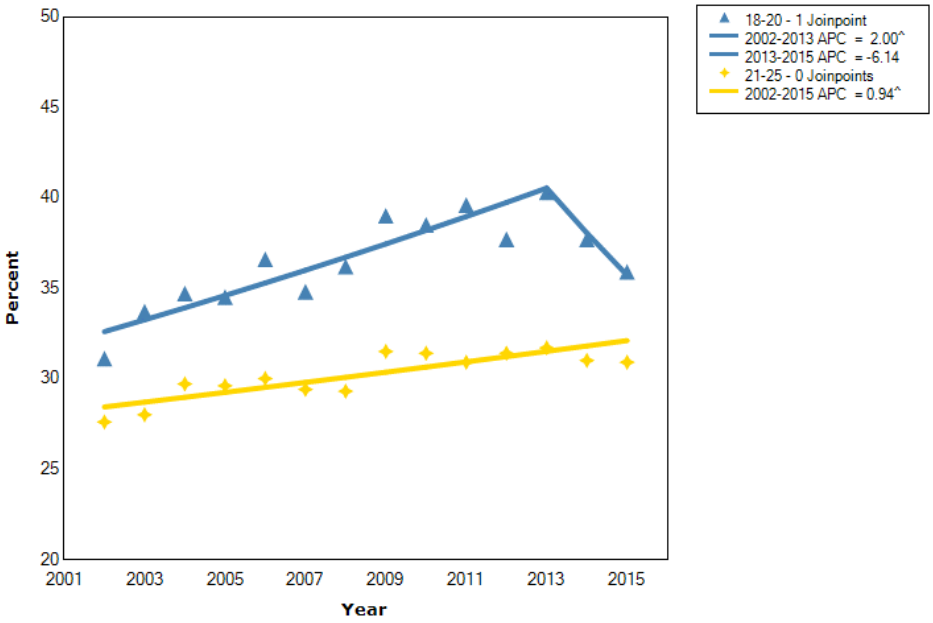


Figure 3.9: Trends of very light smoking by age groups (younger 18-20 years vs older 21-25 years) among young adult ever smokers.



Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

Figure 3.10: Trends of very light smoking by race/ethnicity among young adult ever smokers.

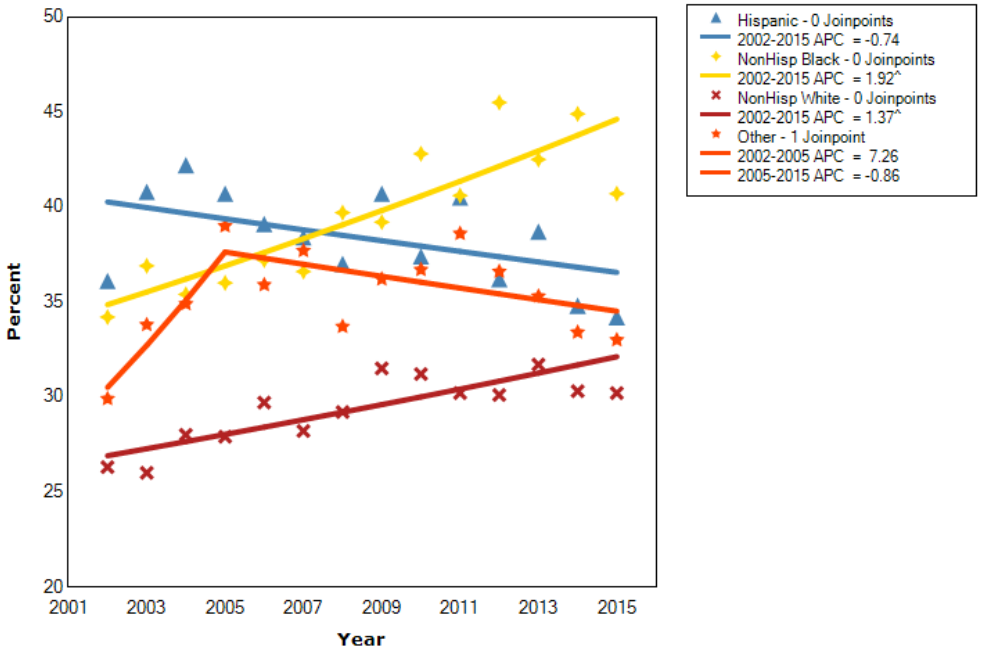
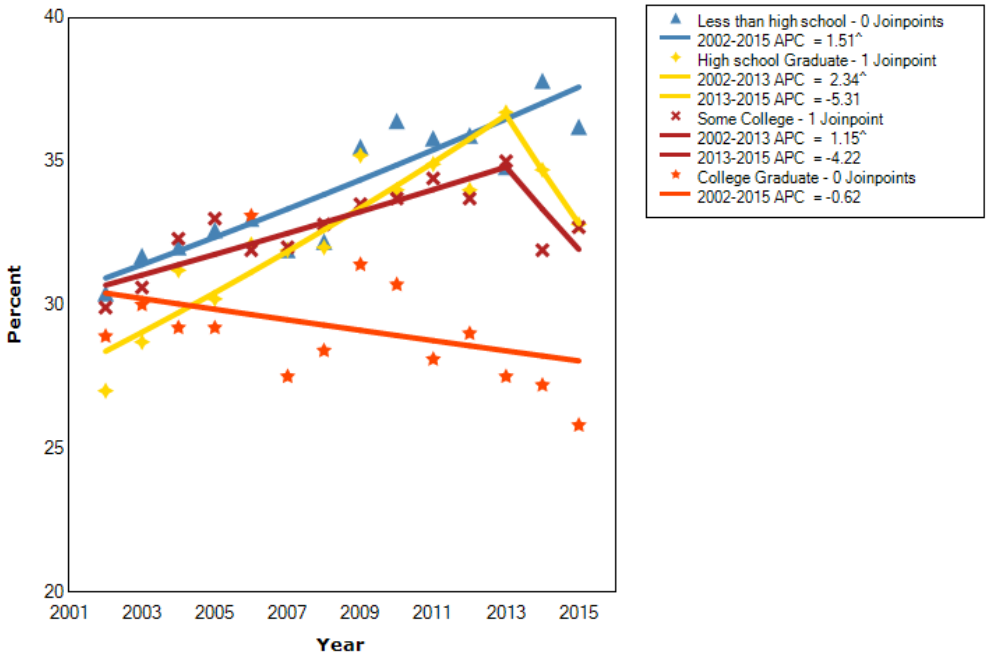


Figure 3.11: Trends of very light smoking by educational level among young adult ever smokers.



Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

Figure 3.12: Trends of very light smoking by educational status (enrolled vs not enrolled) among young adult ever smokers.

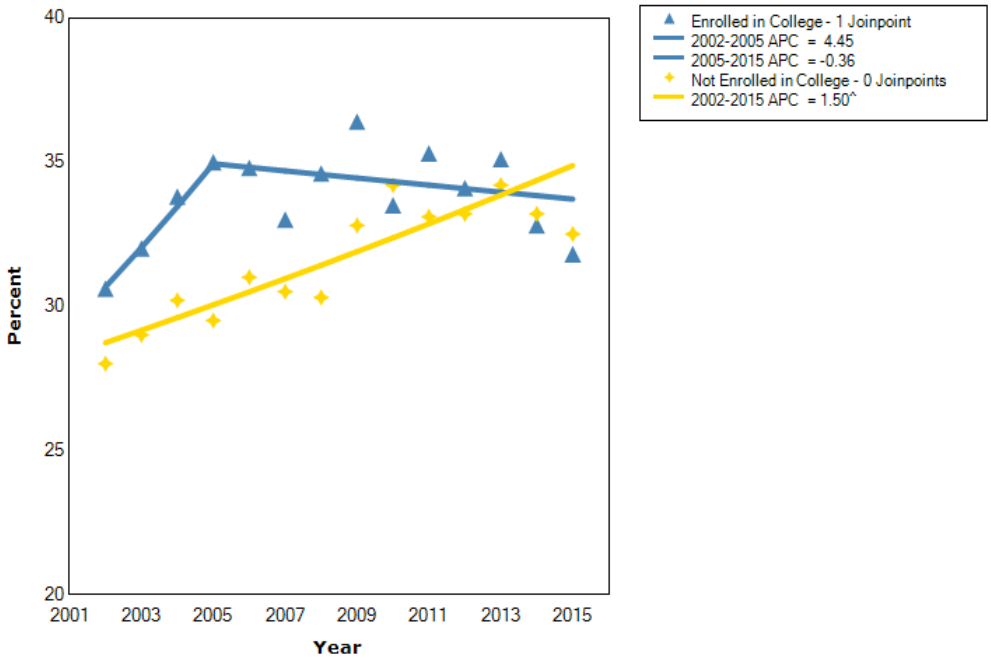
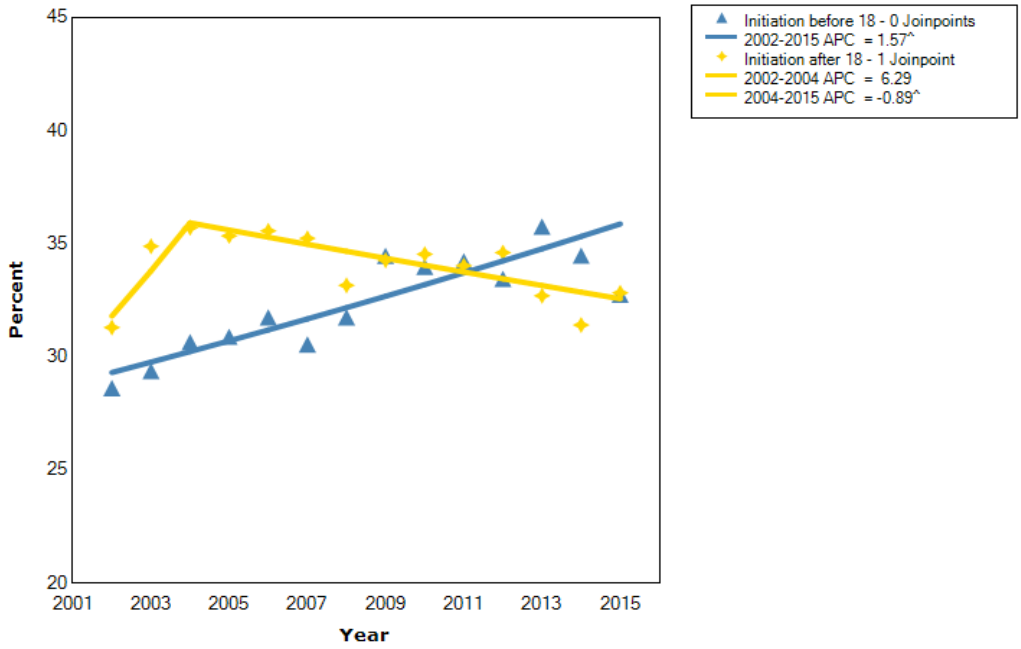
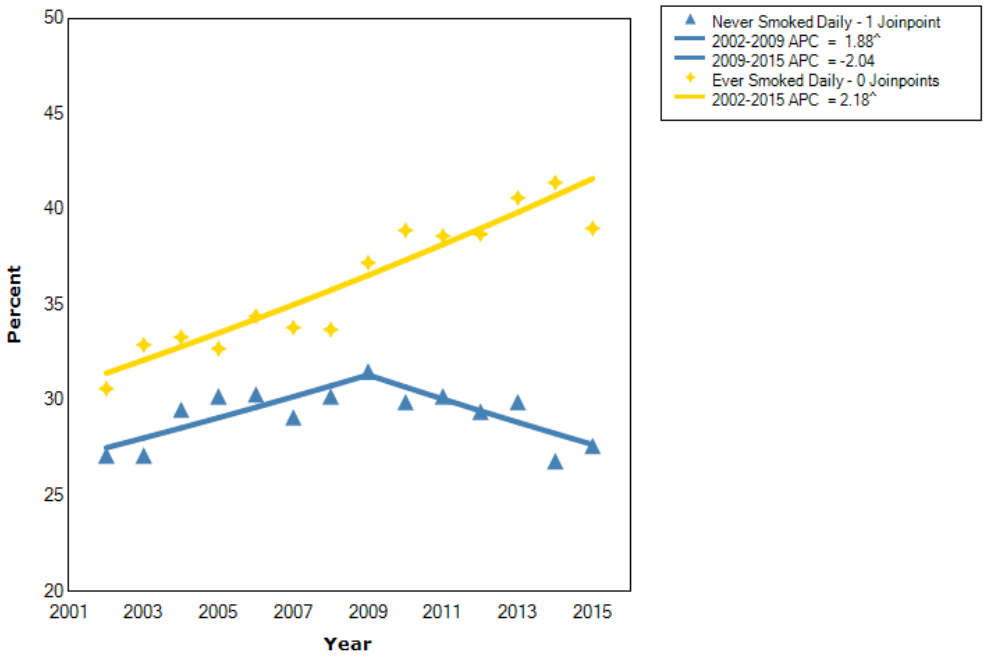


Figure 3.13: Trends of very light smoking by cigarette initiation age (before 18 years vs after 18 years) among young adult ever smokers.



Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

Figure 3.14 Trends of very light smoking by smoking history (have been daily smokers vs never been daily smokers) among young adult ever smokers.



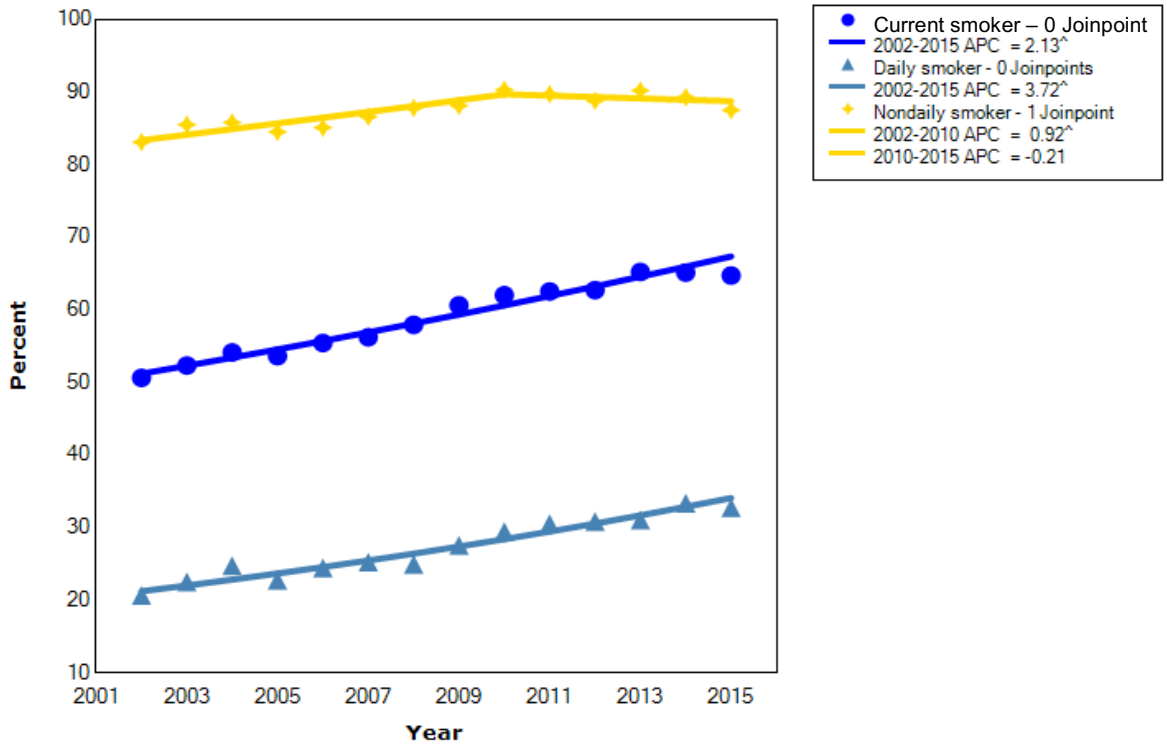
Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

VERY LIGHT SMOKING AMONG CURRENT SMOKERS

A significant linear increase occurred between 2002 and 2015 for the prevalence of very light smoking among young adults who have smoked cigarettes during the past 30 days, from 50.6% in 2002 to 64.7% in 2015 ($p < 0.01$) (See Table 3.3). The annual percent change (APC) was 2.13. In the multivariable logistic regression model run prior to entering the interaction term, the odds of very light smoking were higher among young adults aged 18-20, females, racial/ethnic minorities, college students, and people with a higher educational level compared with their counterparts (See Table 3.6 for average annual prevalence of very light smoking among demographic subpopulations). Controlling for time, sex, age group, race/ethnicity, education level, and education status covariates, daily smoking status, and alternative tobacco use was significantly

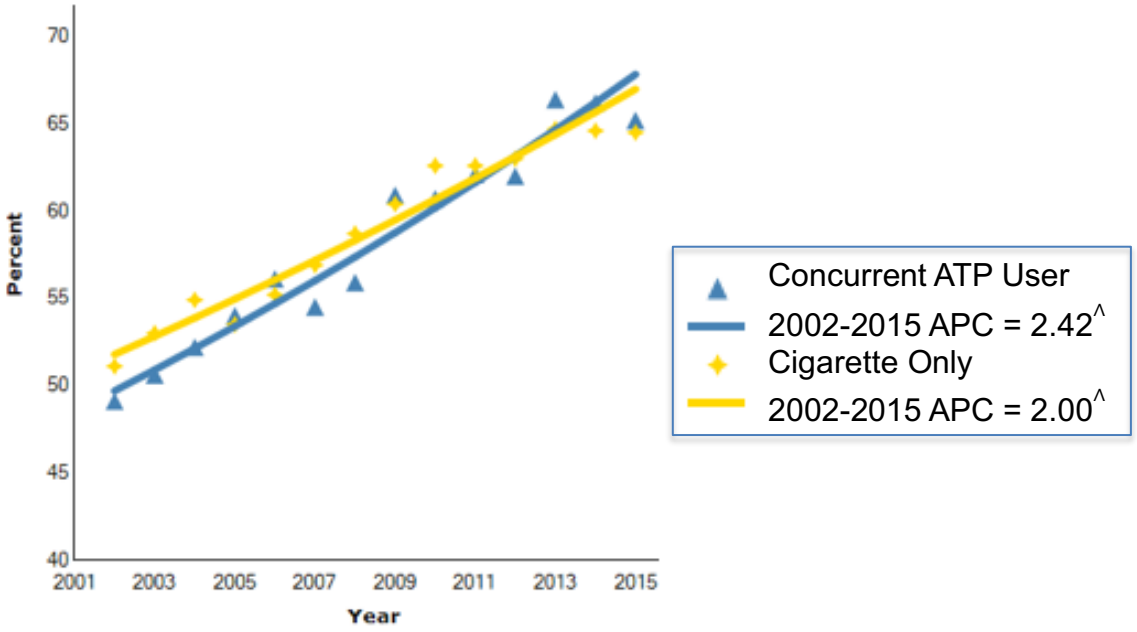
associated with very light smoking status. Compared with daily smokers, nondaily smokers have higher odds of smoking at a very light level (AOR = 16.29, 95% CI = 15.52 - 17.10); compared with concurrent alternative tobacco product users, current cigarette exclusive smokers were more likely to smoke at very light level (AOR = 1.07, 95% CI = 1.02 - 1.13) (data not shown in tables, see Table 3.6, Figure 3.15 and 3.16 for prevalence and joinpoint trend analysis of very light smoking by daily smoking status and concurrent ATP use status).

Figure 3.15: Trends of very light smoking among young adult current smokers and by current daily smoking status (daily vs nondaily) among young adult current smokers.



Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

Figure 3.16: Trends of very light smoking by concurrent alternative tobacco use status (cigarette only vs concurrent ATP use) among young adult current smokers.



Note: ^ Indicate that the annual percent change (APC) is different from zero ($p<0.05$).

To compare the increasing linear trends across subpopulations, additional investigation was conducted using binary logistic regression models that include interaction terms (See Table 3.7). The results confirmed that the trends in very light smoking did not differ by age groups, sex, educational status, education level, daily smoking status, and concurrent ATP use. Although Hispanic current smokers have higher odds of being very light smokers compared to other race/ethnicity groups, the increase was at a significantly lower rate for Hispanic than for Non-Hispanic White current smokers among young adults (Coefficient = -0.030, $p < 0.01$).

TRENDS IN ALTERNATIVE TOBACCO PRODUCT (ATP) USE

Nonlinear trends were detected for ATP user among all young adults, ever smokers, and current smokers (See Table 3.3). From 2002 to 2015, trends of ATP use are significantly quadratic

among all young adults, among young adults who have smoked cigarettes, and among young adults who were current smokers. Among all young adults, the prevalence of current ATP use increased from 15.0% in 2002 to 16.7% in 2010 (APC = 1.03, $p < .05$), and then decreased from 16.8% in 2010 to 14.0% in 2015 (APC = -3.03, $p<.05$); among ever smokers, the prevalence of current ATP use increased from 19.6% in 2002 to 23.7% in 2009 (APC = 2.38, $p < .05$), and then remained unchanged from 2009 to 2015; among current smokers, there is a slight increase of ATP use from 25.7% in 2002 to 29.3% in 2015 (APC = 0.56, $p < .05$) (see Figure 3.17). Additional analysis was conducted to compare trends of ATP use by different smoking level (see Table 3.8 and Figure 3.18). Among very light smokers, the prevalence of current ATP use increased at a relatively high rate from 24.9% in 2002 to 28.3% in 2005 (APC = 4.16, $p < .05$). After 2005, the increase of ATP use among very light smokers slowed down but continued to be significant (APC = 0.66, $p < .05$), and the prevalence reached 29.6% in 2015. Among heavier smokers, the prevalence increased significantly from 26.5% in 2002 to 30.6% in 2010 and then showed a decreasing trend from 2010 to 2015. What is worth noticing is that based on visual trends from 2002 to 2012 the prevalence of ATP use was higher among heavier smokers compared to very light smokers. However, the prevalence of ATP use became higher among very light smokers than among heavier smokers since 2012.

Figure 3.17: Trends of current alternative toacco product use among all young adult, ever smokers, and current smokers.

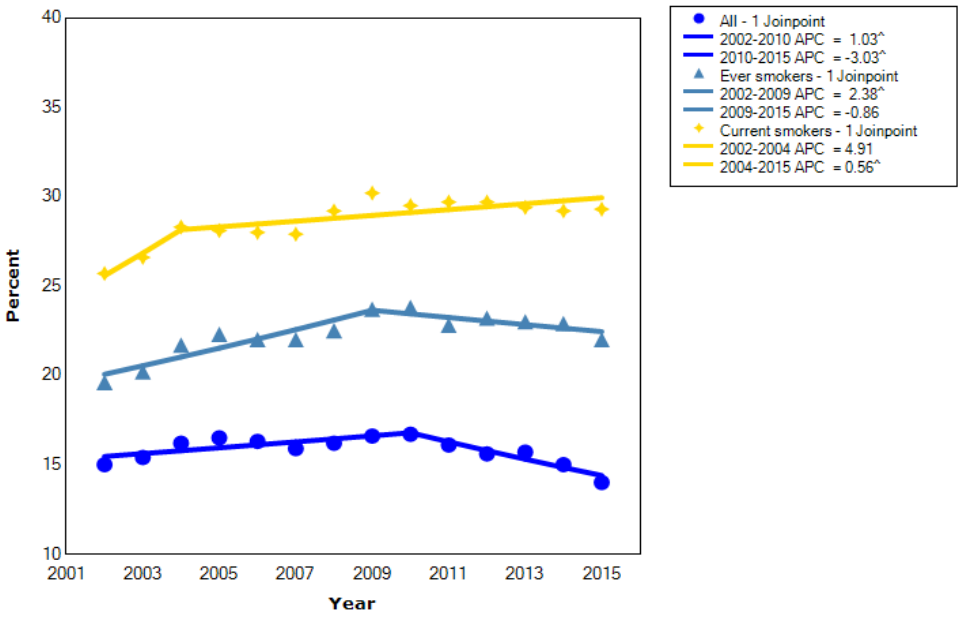
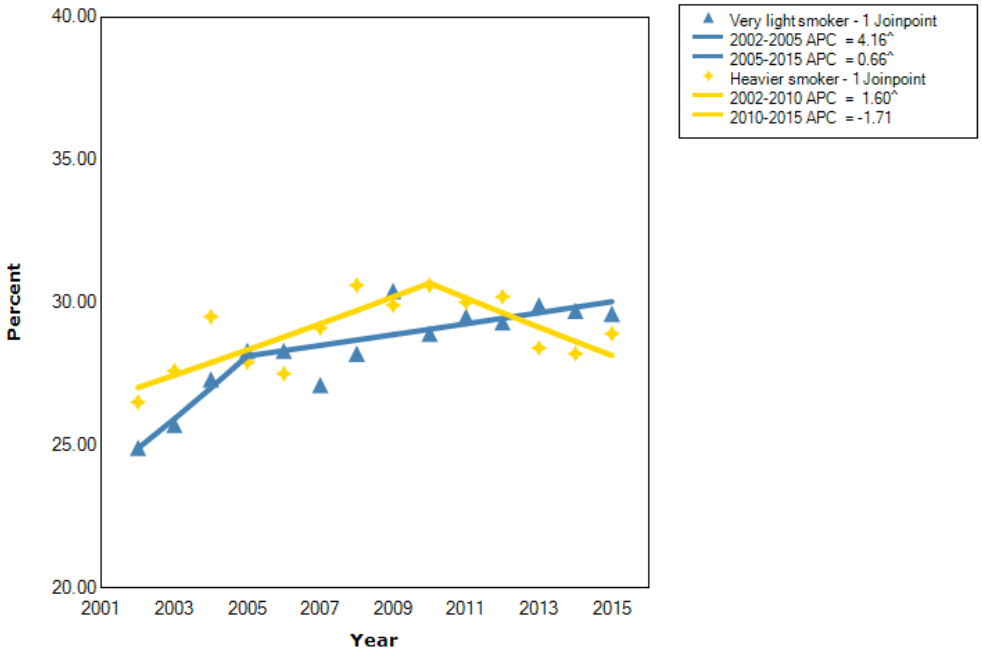


Figure 3.18: Trends of current alternative toacco product use by smoking status (very light vs heavier) among young adult current smokers.



Overall, the author tested the trends of very light smoking among young adults, young adult ever smokers and young adult current smokers. Table 3.9 summarizes the methods and results of this study. Among all young adults, the prevalence of very light smoking has decreased from 2002 to 2015. This general trend, however, masks stable trends in the time period from 2002 to 2011 and in certain subpopulations such as older young adults aged 21 to 25 and non-Hispanic Black young adults. Among young adult ever smokers, prevalence of very light smoking increased from 2002 to 2010 and then change stalled. Across time, very light smoking has been increasing significantly among ever smokers who were male, not enrolled in college, non-Hispanic Black, non-Hispanic White, those who had less than high school education, those who used to be daily smokers and those who initiated smoking before 18 years of age. Among young adults, most current smokers were very light smokers and prevalence of very light smoking increased linearly over time. The trends and the increase in rates of very light smoking were not significantly different when comparing demographic groups, daily smoking status and ATP use status among current smokers. One exception is that compared to White current smokers, very light smoking increased at a slower rate among Hispanic current smokers. In addition to trends of very light smoking, the author also tested the trends of ATP use among young adults, young adult ever smokers and young adult current smokers. Although the trends of ATP use have both increasing and decreasing segments in all young adults and some smoking groups, they remained fairly stable over time. However, among very light smokers, use of ATP increased dramatically from 2002 to 2005 and continued to increase after 2005.

Discussion

Unlike the trend of cigarette smoking in general population, which has shown a clear decline since 1965 (American Lung Association, 2011; Centers for Disease Control and Prevention, 2016b), smoking trends among young adults remain unclear, especially the trends of very light smoking that have developed in recent years. This study examined trends of very light smoking and alternative tobacco product use among young adults aged 18-25 as well as among ever smokers and current smokers in this age range. Analyses were also conducted to examine the socio-demographic (i.e., sex, race/ethnicity, age group, education level, and education status) and behavioral (e.g., daily smoking status and use of alternative tobacco products [ATPs]) determinants of very light smoking trends.

Due to tobacco control efforts, cigarette sales, cigarette consumption, and rates of cigarette smoking have decreased considerably over the past five decades in the United States (Agaku & Alpert, 2016; Al-Delaimy et al., 2007; Substance Abuse and Mental Health Services Administration [SAMHSA], 2012, 2015; USDHHS, 2014). This study confirmed that trends of very light smoking along with other smoking patterns have decreased among young adults from 2002 to 2015. However, when examining the behaviors among different smoking groups, an increasing trend in prevalence of very light smoking was found among ever smokers and current smokers in our study. Successful public health programs and policies may have contributed to the decrease of very light smoking in young adults and the increase of very light smoking in current smokers. However, they may also contribute to the nonlinear trends across time and the health disparity.

Our findings were consistent with previous studies which suggested that the long-term smoking trends among young adults were nonlinear (Nelson et al., 2008). Joinpoint analyses showed that the prevalence of very light smoking remained stable for almost 10 years before its decline in the last five years. Among young adult ever smokers, the prevalence of very light smoking increased in general and in most subpopulations from 2002 to 2010, and this prevalence has remained stable since 2010. In general, different trends of tobacco-related behaviors may reflect implementation of public policies and effectiveness of population-level interventions, such as tobacco tax increases and ban on smoking in public (USDHHS, 2014). Some subpopulations did not benefit from the large-scale public policies or tobacco control strategies, while some subgroups were more protected. For example, the trends of very light smoking did not change significantly among young adults aged 21 to 25, non-Hispanic Blacks, and those who have a less than high school education. Moreover, compared to White current smokers, very light smoking increased at a slower rate among Hispanic current smokers.

In addition to policies and intervention programs, other factors might contribute to the different trends in different subgroups. It has been well established that psychological distress and depression are important factors in young adult smoking (Audrain-McGovern, Rodriguez, Rodgers, & Cuevas, 2011; Bakhshaie, Zvolensky, & Goodwin, 2015; Forman-Hoffman et al., 2017). Smoking motives were also closely related to smoking patterns among young adults. Berg et al. (2012) found that 42% of non-daily college smokers smoked for stress relief or to help with relaxation. Additional research has found that young adult light smokers may smoke for emotional regulation (Brown, Carpenter, & Sutfin, 2011; Darlow & Lobel, 2012; Levinson et al., 2007), especially when they are upset or angry, or to help control depressive symptoms (Berlin et al., 2003; Stromberg et al., 2007). The impact of smoking motives and depression may help explain

the stable prevalence of very light smoking among young adults aged 21 to 25, non-Hispanic Blacks, and those who have a less than high school education.

In line with previous research, this study examined the trends of very light smoking in relation to smoking history and smoking initiation time (Bonnie et al., 2015; Fish et al., 2015; Pinsker et al., 2013). Although converted non-daily smokers (i.e. former daily smokers) and native non-daily smokers (i.e. never daily smokers) were reported to be similar in different ways (Fish et al., 2015; Nguyen & Zhu, 2009), compared to native non-daily smokers, converted non-daily smokers were more likely to feel ready to quit (Pinsker et al., 2013). Our findings showed that very light smoking has been increasing significantly among ever smokers who used to be daily smokers. Although reports from pooled large national surveys stressed that light and/or intermittent smokers were more likely to start smoking after 21 than before 21, analysis from the present study indicated that the prevalence of very light smoking increased among those who initiated smoking before 18 years of age.

With the increasing sales of emerging tobacco products and tobacco marketing strategies targeted to young adults, concurrent use of cigarette and alternative tobacco products has become a public concern (Agaku & Alpert, 2016; Marynak et al., 2017). More than half of cigarette smokers use alternative tobacco products along with cigarettes (Nollen et al., 2016) and concurrent use of cigarette with ATP is increasingly prevalent among young adults (Fix et al., 2014). Although ATPs have been marketed as healthier alternatives to cigarettes that can facilitate smoking reduction and cessation, previous studies showed that very light smokers were more likely to use ATP for socialization purposes (Doran & Brikmanis, 2016; Li et al., 2018). This study is the first known study to investigate the trends of alternative tobacco use by smoking status among young adults. Although the trends of ATP use have both increasing and decreasing segments among all

young adults and some smoking groups, they have remained fairly stable over time. Among very light smokers, use of ATP increased dramatically from 2002 to 2005 and continued to increase after 2005. A deeper investigation into the trends of nicotine exposure among very light smoker is warranted.

Limitations

The present study has several limitations. First, although NSDUH is nationally representative and has been shown to be reliable for generating trends of substance use in the United States, data were self-reported and subject to recall and social desirability bias. Second, this study focuses on the statistical details of current trend testing methods. Each significant increase or decrease in a trend, or a break in a trend, was assumed to represent a real change in a generalized young adult population of the United States. However, evidence of trends may be due to methodological changes of NSDUH. Even when no changes have been made to the survey measures and procedures, some changes may be due to model fit issues or the fact that the estimates are based on samples. The redesign impact analysis work in NSDUH's annual Methodological Resource Book (e.g., Center for Behavioral Health Statistics and Quality, 2016b, in press) explains in detail the factors that can cause a trend or changes in trends. Third, the measure of smoking status was fixed in this secondary data analysis, so there is no way to consider both quantity and frequency of cigarette use in this study. As more and more young adults who are current smokers became very light smokers, measures of cigarette smoking need to be redesigned to include the effects of alternative tobacco product use and other form of nicotine exposure. Fourth, unlike most studies on light and intermittent smoking, the definition of very light smoking was based on the reported number of cigarettes smoked on the one day/days when smoked during the past 30 days.

The effect of daily/intermittent smoking was not examined by definition of very light smoking; instead it was tested by analyzing trends of very light smoking by daily smokers and non-daily smokers. More studies are needed to further differentiate the smokers who only smoked very few days and those who smoked most days during the past 30 days.

Implications

Notwithstanding the above limitations, the current study extends existing research by investigating trends of very light smoking within different socio-demographic and behavioral subgroups and by comparing trends of alternative tobacco use between very light smokers and heavier smokers. Prevention programs need to be tailored for young adults in terms of their psychosocial characteristics and distinct tobacco use patterns. Health education programs together with local, state, and federal regulation of alternative tobacco products, could prevent tobacco initiation, intervene to prevent progression, facilitate cessation, and further reduce overall tobacco use. Measures of cigarette smoking need to be redesigned and further investigation into the trends of nicotine exposure among very light smokers is warranted.

Table 3.1: Demographic distributions of young adults aged 18 to 25: percentages, NSDUH, 2002-2015.[a]

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Sex														
Female	50.0	49.8	49.8	49.7	49.6	49.6	49.7	49.7	49.3	49.9	49.9	49.8	49.8	49.8
Male	50.0	50.2	50.2	50.3	50.4	50.4	50.3	50.3	50.7	50.1	50.1	50.2	50.2	50.2
Age Group														
18-20 year	40.2	39.3	38.7	40.0	38.9	40.5	40.2	40.2	39.6	39.2	38.1	38.0	37.5	37.3
21-25 year	59.8	60.7	61.3	60.0	61.1	59.5	59.8	59.8	60.4	60.8	61.9	62.0	62.5	62.7
Race/Ethnicity														
Non-Hispanic White	62.2	61.9	62	61.8	61.7	61.8	61.7	60.6	59.7	57.2	56.5	56	55.4	55.0
Hispanic	17.7	17.8	17.8	17.7	17.8	17.7	17.6	18.3	19.3	20.5	20.6	20.8	21.1	21.4
Non-Hispanic Black	13.1	13.5	13.5	13.6	13.7	13.8	14.1	14.3	14.3	13.7	14.2	14.4	14.4	14.4
Others	7.0	6.8	6.7	6.8	6.8	6.7	6.7	6.8	6.8	8.6	8.7	8.7	9.1	9.3
Educational Status														
Enrolled in College	37.1	38.0	37.8	38.3	38.6	39.3	39.5	41.0	42.2	42.3	42.4	40.9	40.6	37.3
Not Enrolled	62.9	62.0	62.2	61.7	61.4	60.7	60.5	59.0	57.8	57.7	57.6	59.1	59.4	62.7
Educational Level														
Less than High School	22.4	21.8	20.4	20.5	19.7	18.8	17.8	18	17.1	16.5	15.3	15.9	14.0	15.2
High School Graduate	34.0	34.5	34.7	34.5	34.7	34.2	35.1	34.9	34.6	34.3	34.2	34.5	34.5	31.2
Some College	31.4	31.2	32.2	32.3	32.5	33.7	33.1	32.9	34.3	34.6	35.9	35.0	35.6	40.9
College Graduate	12.2	12.5	12.8	12.7	13.2	13.3	14.0	14.1	14.0	14.6	14.7	14.6	16.0	12.7

Note: a. The average annual sample: 17,828, representing 33,358,047 of the young adult population. Sample size: 13, 069 – 19, 183. Representative population: 31 – 35 million.
b. A respondent was defined as “Enrolled in College” if they were enrolled in school at the college level or higher.

Table 3.2: Tobacco use distributions of young adults aged 18 to 25: percentages, NSDUH, 2002-2015.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Ever any tobacco	75.6	75.1	73.6	72.2	71.6	70.6	70.6	69.7	68.8	68	66.2	65.4	64.3	61.7
se	0.38	0.42	0.53	0.38	0.47	0.50	0.58	0.51	0.46	0.54	0.49	0.52	0.71	0.50
Current any tobacco	45.3	45.1	44.9	44.8	44.2	42.1	41.4	41.8	40.8	39.4	38.1	37.4	35.4	32.8
se	0.58	0.48	0.62	0.45	0.49	0.61	0.56	0.56	0.52	0.56	0.48	0.52	0.69	0.50
Cigarette Smoking														
Ever smokers	71.3	70.4	68.9	67.1	66.3	65	64.6	63.9	62.3	61.1	59.7	58.1	56.5	53.2
se	0.46	0.42	0.58	0.38	0.50	0.48	0.54	0.51	0.50	0.53	0.49	0.56	0.66	0.55
Current smokers	40.7	40.5	40.0	39.4	38.7	36.3	35.5	36.1	34.1	33.2	31.9	30.7	28.7	26.6
se	0.58	0.44	0.58	0.45	0.49	0.54	0.52	0.57	0.52	0.56	0.44	0.52	0.73	0.50
Daily smokers	21.2	21.3	20.8	19.7	18.9	17.9	16.9	16.4	15.8	15.2	14.3	13.0	12.4	11.1
se	0.43	0.49	0.43	0.36	0.40	0.37	0.38	0.36	0.36	0.37	0.4	0.31	0.39	0.34
Non-daily smokers	19.5	19.2	19.3	19.7	19.8	18.4	18.6	19.7	18.3	18	17.6	17.7	16.3	15.6
se	0.45	0.39	0.47	0.36	0.41	0.42	0.42	0.41	0.44	0.40	0.48	0.43	0.54	0.47
Exclusive Cigarette	30.3	29.7	28.7	28.3	27.9	26.1	25.2	25.2	24	23.3	22.4	21.7	20.3	18.8
se	0.51	0.37	0.45	0.41	0.46	0.48	0.47	0.51	0.47	0.45	0.44	0.45	0.59	0.39
Current Poly User (Cigarette + ATP)	10.5	10.8	11.3	11.1	10.8	10.1	10.4	10.9	10.1	9.9	9.5	9.0	8.4	7.8
se	0.29	0.30	0.31	0.23	0.36	0.32	0.34	0.33	0.37	0.33	0.24	0.24	0.35	0.32
Exclusive ATP User	4.5	4.7	4.9	5.4	5.5	5.8	5.8	5.7	6.7	6.2	6.2	6.7	6.7	6.2
se	0.18	0.23	0.20	0.22	0.26	0.25	0.25	0.23	0.24	0.27	0.26	0.24	0.27	0.31

Table 3.3: Summary of trend analyses of very light smoking and alternative tobacco product use prevalence among all young adults, ever smokers, and current smokers selected from NSDUH 2002 to 2015[a].

	All Young Adults			
	Trend	Estimate	*SE*	*p*
Very light smoking	Cubic	-0.08	0.03	0.0139
Alternative tobacco use	Quadratic	-0.17	0.03	<0.0001
	Ever Smokers			
	Trend	Estimate	*SE*	*p*
Very light smoking	Quadratic	-0.14	0.03	<0.0001
Alternative tobacco use	Quadratic	-0.16	0.03	<0.0001
	Current smokers			
	Trend	Estimate	*SE*	*p*
Very light smoking	Linear	0.77	0.04	<0.0001
Alternative tobacco use	Quadratic	-0.12	0.04	0.0057

Note: [a] Based on linear, quadratic, and cubic trend analyses using logistic regression models controlling for age group, sex, race/ethnicity, educational level and educational status, $p < 0.05$

Table 3.4: Prevalence and standard error (SE) of very light smoking by sex, age group, race/ethnicity, educational level, and educational status among all young adults, NSDUH, 2002-2015.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total	20.6	21.2	21.6	21.1	21.4	20.3	20.5	21.8	21.1	20.7	20.0	20.0	18.6	17.2
se	0.46	0.32	0.52	0.43	0.39	0.46	0.44	0.5	0.42	0.39	0.43	0.47	0.58	0.54
Sex														
Female	19.2	19.4	20.3	19.4	19.7	18.3	19.2	19.5	18.8	18.4	17.5	16.8	15.8	14.8
se	0.57	0.55	0.65	0.61	0.62	0.55	0.57	0.59	0.57	0.57	0.58	0.55	0.78	0.51
Male	21.9	22.9	23.0	22.7	23.1	22.4	21.9	24.2	23.3	23.0	22.5	23.2	21.5	19.6
se	0.54	0.57	0.75	0.61	0.49	0.67	0.62	0.76	0.58	0.59	0.65	0.7	0.75	0.87
Age Group														
Younger (18-20)	21	22.4	22.2	21.5	21.9	20.6	21.2	22.2	21.5	21.3	19.7	19.6	17.4	15.3
se	0.66	0.62	0.77	0.54	0.61	0.72	0.69	0.78	0.59	0.69	0.68	0.74	0.77	0.93
Older (21-25)	20.3	20.4	21.3	20.8	21.1	20.2	20.1	21.6	20.8	20.3	20.2	20.2	19.4	18.4
se	0.59	0.51	0.62	0.57	0.52	0.53	0.53	0.56	0.56	0.48	0.52	0.59	0.81	0.59
Race/Ethnicity														
White	20.3	19.7	20.9	20.4	21.7	19.8	20.6	22.0	21.2	20.3	19.6	20.5	19.1	17.7
se	0.49	0.47	0.52	0.54	0.53	0.5	0.56	0.65	0.46	0.49	0.54	0.59	0.68	0.64
Hispanic	23.1	27.0	26.1	24.8	22.9	22.8	23.0	24.5	22.3	23.3	21.1	21.2	18.4	17.1
se	1.17	1.00	1.49	1.13	0.97	1.26	0.89	1.19	1.07	1.15	0.95	0.99	1.07	1.13
Non-Hispanic Black	19.4	20.6	19.9	19.3	18.8	18.5	18.6	18.7	19.5	18.9	21.1	18.5	19.5	16.9
se	1.08	1.16	0.90	1.10	0.92	1.15	1.00	1.01	0.98	1.00	1.05	1.14	1.80	0.99
Others	19.3	20.5	20.3	21.3	19.7	22.7	17.3	19.3	19.8	20.1	17.8	16.5	14.9	15.0
se	1.41	1.68	1.65	1.60	1.60	1.45	1.35	1.44	1.92	1.59	1.24	1.36	1.28	1.47
Educational Level														
Less than high school	22.0	22.6	22.4	22.4	22.0	21.3	21.6	23.4	23.4	23.3	23.2	21.2	23.1	19.6
se	0.83	0.81	0.95	1.07	0.79	1.17	1.02	1.18	0.90	1.07	0.98	1.11	1.21	1.22
High school graduate	19.3	20.2	21.4	20.4	21.5	20.8	20.7	22.8	21.2	21.6	20.8	21.2	19.6	17.9
se	0.65	0.63	0.72	0.67	0.68	0.72	0.71	0.75	0.66	0.81	0.71	0.83	0.86	0.94
Some college	21.2	21.7	22.1	21.8	20.8	20.7	20.8	20.9	21.0	20.6	19.3	20.2	17.8	16.9

Table 3.4, cont.

	se	0.73	0.77	0.90	0.65	0.68	0.67	0.71	0.88	0.64	0.64	0.75	0.67	0.86	0.79
	College graduate	20.2	20.0	19.7	18.8	21.9	17.1	18.0	19.6	18.3	15.9	16.5	15.4	14.5	13.7
	se	1.18	1.04	1.19	1.23	1.41	1.11	1.19	0.97	1.23	1.17	1.03	1.19	1.20	1.06
Educational Status															
	College students	20.3	21.4	21.5	21.7	21.1	19.8	20.3	21.2	19.0	19.3	17.6	17.9	15.4	13.9
	se	0.69	0.73	0.82	0.55	0.58	0.63	0.81	0.83	0.60	0.59	0.56	0.63	0.61	0.81
	Not enrolled	20.8	21.0	21.7	20.7	21.6	20.7	20.7	22.3	22.7	21.8	21.7	21.5	20.8	19.2
	se	0.48	0.49	0.57	0.56	0.55	0.64	0.53	0.52	0.55	0.54	0.55	0.51	0.77	0.62

Table 3.5: Prevalence and standard error (SE) of very light smoking by sex, age group, race/ethnicity, educational level, educational status, cigarette initiation age, and smoking history among young adult ever smokers, NSDUH, 2002-2015.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total	28.9	30.1	31.5	31.5	32.3	31.4	31.8	34.2	33.9	33.9	33.5	34.5	33.1	32.4
se	0.61	0.45	0.67	0.62	0.56	0.62	0.62	0.67	0.64	0.51	0.65	0.69	0.85	0.91
Sex														
Female	28.1	28.6	31.1	30.2	30.9	30.0	31.3	32.4	32.5	32.6	31.4	31.8	30.6	30.2
se	0.74	0.83	0.94	0.88	0.91	0.80	0.85	0.85	0.93	0.78	0.87	0.96	1.32	1.01
Male	29.7	31.5	31.8	32.6	33.6	32.6	32.4	35.7	35.1	35.1	35.3	36.7	35.1	34.3
se	0.71	0.69	0.96	0.78	0.64	0.88	0.82	1.00	0.82	0.85	0.97	0.97	1.04	1.35
Age Group														
Younger (18-20)	31.1	33.7	34.7	34.5	36.6	34.8	36.2	39.0	38.5	39.6	37.7	40.3	37.7	35.9
se	0.83	0.81	0.98	0.83	0.94	0.98	1.04	1.17	0.93	0.98	1.18	1.22	1.52	1.55
Older (21-25)	27.6	28.0	29.7	29.6	30.0	29.4	29.3	31.5	31.4	30.9	31.4	31.7	31.0	30.9
se	0.79	0.71	0.82	0.72	0.72	0.71	0.73	0.79	0.79	0.63	0.72	0.80	1.13	0.94
Race/Ethnicity														
White	26.3	26	28	27.9	29.7	28.2	29.2	31.5	31.2	30.2	30.1	31.7	30.3	30.2
se	0.60	0.62	0.67	0.70	0.69	0.72	0.72	0.80	0.62	0.67	0.73	0.86	0.95	1.00
Hispanic	36.1	40.8	42.2	40.7	39.1	38.4	37.0	40.7	37.4	40.5	36.2	38.7	34.8	34.2
se	1.60	1.50	1.93	1.58	1.37	1.82	1.14	1.67	1.63	1.80	1.66	1.51	1.76	1.88
Non-Hispanic Black	34.2	36.9	35.4	36	37.2	36.6	39.7	39.2	42.8	40.6	45.5	42.5	44.9	40.7
se	1.78	1.72	1.79	1.73	1.69	1.99	1.64	1.57	1.79	1.68	1.85	2.18	2.86	1.99
Others	29.9	33.8	34.9	39.0	35.9	37.7	33.7	36.2	36.7	38.6	36.6	35.3	33.4	33.0
se	1.96	2.25	2.52	2.64	2.30	2.01	1.87	2.23	2.51	2.29	2.15	2.16	2.65	2.36
Educational Level														
Less than high school	30.4	31.7	32.0	32.6	33.0	31.9	32.2	35.5	36.4	35.8	35.9	34.8	37.8	36.2
se	1.10	1.07	1.24	1.38	1.10	1.49	1.38	1.47	1.20	1.42	1.44	1.61	1.73	1.93
High school graduate	27.0	28.7	31.2	30.2	32.1	31.9	32.0	35.2	34.0	34.9	34.0	36.7	34.7	32.8
se	0.82	0.84	0.97	0.91	0.95	1.00	1.00	1.02	0.98	1.07	1.07	1.17	1.29	1.44
Some college	29.9	30.6	32.3	33.0	31.9	32.0	32.8	33.5	33.7	34.4	33.7	35.0	31.9	32.7

Table 3.5, cont.

se	0.92	1.00	1.22	0.96	0.96	0.96	0.99	1.18	0.93	0.90	1.19	1.11	1.27	1.36
College graduate	28.9	30.0	29.2	29.2	33.1	27.5	28.4	31.4	30.7	28.1	29.0	27.5	27.2	25.8
se	1.71	1.45	1.71	1.59	1.88	1.74	1.71	1.44	1.80	1.94	1.57	1.80	2.30	1.84
Educational Status														
College students	30.6	32.0	33.8	35.0	34.8	33.0	34.6	36.4	33.5	35.3	34.1	35.1	32.8	31.8
se	0.85	0.99	1.07	0.94	0.95	0.88	1.20	1.14	1.03	0.83	0.95	1.17	1.14	1.37
Not enrolled	28.0	29.0	30.2	29.5	31.0	30.5	30.3	32.8	34.2	33.1	33.2	34.2	33.2	32.5
se	0.64	0.63	0.70	0.74	0.77	0.81	0.71	0.73	0.70	0.74	0.77	0.69	1.04	1.02
Cigarette Initiation Age														
Before age 18	28.6	29.4	30.6	30.9	31.7	30.5	31.7	34.5	34.0	34.2	33.4	35.8	34.5	32.7
se	0.69	0.52	0.69	0.72	0.64	0.69	0.64	0.76	0.73	0.74	0.83	0.72	0.96	1.06
After age 18	31.3	34.9	35.7	35.3	35.6	35.2	33.2	34.3	34.5	34.0	34.6	32.7	31.4	32.8
se	1.35	1.50	1.27	1.38	1.17	1.30	1.21	1.18	1.35	1.05	1.07	1.25	1.30	1.20
Smoking History														
Never smoked daily	27.1	27.1	29.5	30.2	30.3	29.1	30.2	31.5	29.9	30.2	29.4	29.9	26.8	27.6
se	0.88	0.63	0.82	0.74	0.76	0.85	0.92	0.90	0.86	0.84	0.91	0.78	1.03	1.00
Ever smoked daily	30.6	32.9	33.3	32.7	34.4	33.8	33.7	37.2	38.9	38.6	38.7	40.6	41.4	39.0
se	0.74	0.53	0.93	0.88	0.78	0.76	0.85	0.84	0.93	0.91	0.92	1.04	0.97	1.34

Table 3.6: Prevalence and standard error (SE) of very light smoking by sex, age group, race/ethnicity, educational level, educational status, daily smoking status and alternative tobacco product (ATP) use status among young adult current smokers, NSDUH, 2002-2015.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total	50.6	52.3	54.1	53.6	55.4	56.2	57.9	60.6	62.0	62.5	62.7	65.2	65.1	64.7
se	0.79	0.67	0.82	0.81	0.80	0.77	0.85	0.87	0.83	0.75	0.92	0.88	0.97	1.28
Sex														
Female	52.2	53.2	56.8	54.9	56.0	57.5	60.8	61.2	62.4	64.9	64.4	67.3	68.1	66.0
se	1.12	1.14	1.28	1.20	1.27	1.04	1.14	1.25	1.31	1.14	1.12	1.35	1.68	1.64
Male	49.3	51.6	52.0	52.6	54.9	55.2	55.5	60.0	61.7	60.7	61.5	63.8	63.1	63.8
se	0.92	0.82	1.23	1.01	0.87	1.07	1.15	1.16	1.00	1.06	1.26	1.23	1.31	1.66
Age Group														
Younger (18-20)	55.1	57.8	58.6	59.7	61.7	62.2	63.3	66.3	68.8	68.8	69.7	72.8	71.4	72.6
se	1.21	1.20	1.35	1.20	1.33	1.26	1.39	1.22	1.11	1.19	1.35	1.27	1.65	1.92
Older (21-25)	47.9	49.1	51.5	50.1	51.9	52.7	54.5	57.2	58.2	58.9	59.2	61.4	62.1	61.4
se	1.02	0.96	1.07	1.04	1.08	1.00	1.00	1.07	1.13	0.92	1.12	1.15	1.30	1.39
Race/Ethnicity														
White	43.2	43.2	45.8	45.7	48.8	48.3	50.9	53.4	54.6	53.9	53.5	57.1	56.2	57.6
se	0.86	0.93	0.91	0.95	0.99	0.98	1.00	1.11	1.01	1.07	0.86	1.15	1.20	1.62
Hispanic	75.2	79.2	81.8	76.6	78.9	79.2	77.7	83.8	82.3	84.6	82.1	85.5	83.4	82.2
se	1.95	1.45	1.72	1.87	1.89	2.09	1.74	1.44	1.79	1.56	2.24	1.58	2.35	2.07
Non-Hispanic Black	70.0	72.1	66.3	67.7	68.8	70.6	72.1	71.3	75.2	75.9	81.1	77.4	84.0	76.7
se	2.49	2.02	2.42	2.30	2.24	2.49	1.91	2.05	1.98	1.95	1.47	1.96	2.19	2.10
Others	55.2	60.5	67.6	69.8	59.7	70.8	68.5	67.8	71.3	67.9	72.6	74.1	75.4	67.2
se	3.31	2.65	2.80	3.26	2.87	2.79	2.72	3.35	3.31	2.95	2.91	2.78	2.66	3.32
Educational Level														
Less than High School	45.9	46.2	45.2	47.7	47.4	47.1	48.1	51.0	53.0	52.6	53.9	52.6	57.3	58.1
se	1.41	1.37	1.60	1.50	1.55	1.82	1.73	1.69	1.60	1.44	1.87	2.01	2.18	2.35
High School Graduate	45.3	47.3	51.4	48.2	50.7	52.5	53.3	56.5	56.4	57.7	58.0	63.3	61.2	59.9
se	1.15	1.20	1.28	1.34	1.25	1.29	1.38	1.44	1.23	1.43	1.47	1.40	1.63	1.78

Table 3.6, cont.

Some College	56.1	59.0	60.2	60.8	61.3	63.3	65.0	67.8	69.2	70.5	68.8	71.1	68.8	69.6
se	1.32	1.37	1.67	1.26	1.47	1.36	1.39	1.40	1.49	1.31	1.64	1.47	1.84	1.87
College Graduate	67.4	70.4	69.9	69.3	75.8	72.1	77.8	78.1	83.4	81.4	81.2	81.0	83.9	78.9
se	1.98	2.25	2.65	2.41	2.53	2.54	2.37	1.95	1.98	2.81	2.03	2.53	3.04	3.91
Educational Status														
College students	59.5	64.7	66.4	68.3	68.6	69.4	69.9	73.4	72.6	76.3	75.3	77.8	78.4	79.0
se	1.16	1.31	1.31	1.35	1.22	1.25	1.52	1.06	1.50	1.18	1.20	1.53	1.55	1.70
Not enrolled	46.6	46.8	48.7	47.1	49.6	50.3	52.1	54.2	57.0	56.0	57.1	59.7	59.9	59.9
se	0.83	0.84	0.90	1.01	1.02	0.97	1.05	0.98	0.89	0.99	1.12	0.95	1.25	1.49
Current Daily Smoking Status														
Daily smokers	20.6	22.5	24.7	22.7	24.4	25.2	24.9	27.5	29.4	30.5	30.8	31.0	33.3	32.7
se	0.71	0.85	1.12	1.06	0.90	0.91	0.89	0.99	1.12	1.15	1.28	1.17	1.34	1.71
Nondaily smokers	83.1	85.5	85.8	84.5	85.1	86.6	87.8	88.1	90.3	89.7	88.8	90.2	89.3	87.5
se	0.72	0.82	0.73	0.76	0.99	0.80	0.70	0.74	0.55	0.62	0.81	0.75	0.81	0.92
Current ATP Use Status														
Exclusive Cigarette	51.1	53.0	54.9	53.5	55.2	56.9	58.7	60.4	62.6	62.6	63.0	64.7	64.6	64.5
se	0.95	0.88	0.98	0.86	1.08	0.82	1.04	0.92	1.09	0.84	1.14	1.04	1.14	1.40
Current Cigarette + ATP	49.1	50.6	52.2	54	56.1	54.5	55.9	60.9	60.7	62.1	62.0	66.4	66.2	65.2
se	1.60	1.38	1.57	1.62	1.55	1.44	1.46	1.78	1.37	1.62	1.30	1.41	1.90	2.09

Table 3.7: Linear Trend Comparisons across subpopulations of very light smoking among young adult current smokers, NSDUH, 2002-2015.

Variable	Coefficient	*SE*	*p*
Linear trend	0.048	0.009	<.0001
Daily smoking status			
Nondaily current smokers	2.851	0.048	<.0001
Daily smokers	*ref*		
time1*daily_c	-0.010	0.007	0.156
Current ATP use			
Cigarette only smoker	0.114	0.054	0.035
Concurrent ATP user	*ref*		
time1*cuatp	-0.008	0.007	0.261
Age group			
18-20 year	0.409	0.057	<.0001
21-25 year	*ref*		
linear * 18-20 year	0.012	0.008	0.130
Sex			
Female	0.316	0.036	<.0001
Male	*ref*		
linear * Female	0.011	0.006	0.068
Race			
Hispanic	1.478	0.081	<.0001
NonHisp Black	1.084	0.075	<.0001
Others	0.673	0.101	<.0001
NonHisp White	*ref*		
linear * Hispanic	-0.030	0.011	0.009
linear * NonHisp Black	0.007	0.011	0.527
linear * Others	-0.004	0.013	0.765
Educational Status			
Enrolled in college	0.247	0.052	<.0001
Not Enrolled in college	*ref*		
linear * Enrolled	0.006	0.008	0.469
Educational Level			
High school graduate	0.161	0.055	0.004
Some college	0.418	0.059	<.0001
College graduate	0.767	0.092	<.0001
Less than high school	*ref*		
linear * High school graduate	0.003	0.008	0.683
linear * Some college	-0.002	0.009	0.844
linear * College graduate	0.021	0.014	0.151

Table 3.8: Prevalence and standard error (SE) of current alternative tobacco product (ATP) use by smoking status among young adult, NSDUH, 2002-2015.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Among Young Adults	15.0	15.4	16.2	16.5	16.3	16.0	16.2	16.6	16.8	16.1	15.6	15.7	15.0	14.0
se	0.33	0.39	0.39	0.33	0.42	0.39	0.44	0.39	0.48	0.40	0.34	0.35	0.36	0.41
Among Ever Smokers	19.6	20.2	21.7	22.3	22.0	22.0	22.5	23.7	23.8	22.8	23.2	23.0	22.9	22.0
se	0.45	0.47	0.55	0.44	0.58	0.55	0.61	0.56	0.69	0.54	0.54	0.52	0.53	0.62
Among Current Smokers	25.7	26.6	28.3	28.1	28.0	27.9	29.2	30.2	29.5	29.7	29.7	29.4	29.2	29.3
se	0.64	0.64	0.62	0.53	0.83	0.78	0.85	0.81	0.94	0.80	0.76	0.67	0.96	0.95
Among Light Smokers	24.9	25.7	27.3	28.3	28.3	27.1	28.2	30.4	28.9	29.5	29.3	29.9	29.7	29.6
se	1.02	0.89	0.81	0.89	1.07	1.02	1.18	1.16	1.20	1.07	0.88	0.88	1.18	1.20
Among Heavier Smokers	26.5	27.6	29.5	27.9	27.5	29.1	30.6	29.9	30.6	30.0	30.2	28.4	28.2	28.9
se	0.92	1.01	1.14	0.89	1.30	0.96	1.05	1.17	1.27	1.23	1.27	1.17	1.66	1.60

Table 3.9: Summary table of study 1 methods and results.

Sample	Analysis	Figures & Tables	Important Findings
Young adults (aged 18-25 selected from NSDUH 2002-2015)	Three-step trend analysis of very light smoking; covariates include: sex, age group, race/ethnicity, educational status, educational level.		
	Step 1: Trend test	Table 3.3	Cubic Trend ($p < 0.05$)
	Step 2: Joinpoint regression among young adults	Figure 3.1	2002-2011 APC = - 0.05 2011-2015 APC = -4.13*
	Step 3: Joinpoint regression among subgroups: sex, age group, race/ethnicity, educational status, educational level.	Figure 3.2-Figure 3.6	2011-2015, prevalence decreased significantly among most demographic subpopulations; trends did not change among young adults aged 21 to 25, non-Hispanic Black and those who have less than high school education
	Trend test and joinpoint analysis of alternative tobacco use	Table 3.3 & Figure 3.17	Quadratic trend ($p < 0.01$)
Young adult ever smokers (aged 18-25 selected from NSDUH 2002-2015; have ever smoked part or all of a cigarette)	Three-step trend analysis of very light smoking; covariates include: sex, age group, race/ethnicity, educational status, educational level, age of cigarette initiation, and smoking history.		
	Step 1: Trend test	Table 3.3	Quadratic trend ($p < 0.01$)

Table 3.9, cont.

	Step 2: Joinpoint regression among young adult ever smokers	Figure 3.7	2002-2010 APC = 1.78* 2010-2015 APC = -0.54
Young adult ever smokers (aged 18-25 selected from NSDUH 2002-2015; have ever smoked part or all of a cigarette)	Step 3: Joinpoint regression among subgroups: sex, age group, race/ethnicity, educational status, educational level, age of cigarette initiation, and smoking history.	Figure 3.8-Figure 3.14	Prevalence increased among most ever smoker subpopulations; trend remains stable in Hispanic and Other, college graduates, and enrolled college students; the prevalence started to show decreasing trends in recent years among female, aged 18-20, graduated from high school, had some college education, and those who had never been daily smokers
	Trend test and joinpoint analysis of alternative tobacco use	Table 3.3 & Figure 3.17	Quadratic trend ($p < 0.01$)
Young adult current smokers (aged 18-25 selected from NSDUH 2002-2015; have smoked within the past 30 days)	Three-step rend analysis of very light smoking: covariates include: sex, age group, race/ethnicity, educational status, educational level, daily smoking status, and current ATP use		
	Step 1: Trend test	Table 3.3	Linear trend (Coefficient = 0.048, $p < 0.01$)

Table 3.9, cont.

Young adult current smokers (aged 18-25 selected from NSDUH 2002-2015; have smoked within the past 30 days)	Step 2: Compared linear trends across subpopulations by including interactions: sex × time, age group × time, race/ethnicity × time, education level × time, education status × time, daily smoking status × time, and current ATP use × time)	Table 3.7	The increase was at a significantly lower rate for Hispanic than for Non-Hispanic White current smokers among young adults (Coefficient = -0.030, $p < 0.01$)
	Step 3: Joinpoint regression among subgroups: daily smoking and current ATP use	Figure 3.15 & Figure 3.16	Linear increase
	Trend test and joinpoint analysis of alternative tobacco use	Table 3.3 & Figure 3.17	Quadratic trend ($p < 0.01$) 2002-2010 APC = 1.03* 2010-2015 APC = - 3.03*
	Joinpoint regression of alternative tobacco use among two smoking groups	Figure 3.18	Among very light smokers, the prevalence of current ATP use increased at a relatively high rate from 2002 to 2005 (APC = 4.16, $p < .05$). After 2005, the increase slowed down but continued to be significant (APC = 0.66, $p < .05$). Among heavier smokers, the prevalence increased significantly from 2002 to 2010 and then showed a decreasing trend from 2010 to 2015. The prevalence of ATP use became higher among very light smokers than among heavier smokers since 2012.

References

Agaku, I. T., & Alpert, H. R. (2016). Trends in annual sales and current use of cigarettes, cigars, roll-your-own tobacco, pipes, and smokeless tobacco among US adults, 2002–2012. *Tobacco Control*, *25*(4), 451–457. https://doi.org/10.1136/tobaccocontrol-2014-052125

Al-Delaimy, W. K., Pierce, J. P., Messer, K., White, M. M., Trinidad, D. R., & Gilpin, E. A. (2007). The California Tobacco Control Program's effect on adult smokers: (2) Daily cigarette consumption levels. *Tobacco Control*, *16*(2), 91–95. https://doi.org/10.1136/tc.2006.017061

American Lung Association. (2011). Trends in tobacco use. *Washington, DC: American Lung Association*.

Arnett, J. J. (2000). Emerging adulthood: A theory of development from the late teens through the twenties. *American Psychologist*, *55*(5), 469–480. https://doi.org/10.1037//0003-066X.55.5.469

Arnett, J. J. (2005). The Developmental Context of Substance use in Emerging Adulthood. *Journal of Drug Issues*, *35*(2), 235–254. https://doi.org/10.1177/002204260503500202

Audrain-McGovern, J., Rodriguez, D., Rodgers, K., & Cuevas, J. (2011). Declining alternative reinforcers link depression to young adult smoking: Depression, alternative reinforcers and smoking. *Addiction*, *106*(1), 178–187. https://doi.org/10.1111/j.1360-0443.2010.03113.x

Bakhshaie, J., Zvolensky, M. J., & Goodwin, R. D. (2015). Cigarette smoking and the onset and persistence of depression among adults in the United States: 1994–2005. *Comprehensive Psychiatry*, *60*, 142–148. https://doi.org/10.1016/j.comppsych.2014.10.012

Bonnie, R. J., Stratton, K., & Kwan, L. Y. (Eds.). (2015). Patterns of Tobacco Use by Adolescents and Young Adults. In *Public health implications of raising the minimum age of legal access to tobacco products*. Washington, D.C: The National Academies Press.

Caldeira, K. M., O'Grady, K. E., Garnier-Dykstra, L. M., Vincent, K. B., Pickworth, W. B., & Arria, A. M. (2012). Cigarette smoking among college students: longitudinal trajectories and health outcomes. *Nicotine and Tobacco Research*, *14*(7), 777–785. https://doi.org/10.1093/ntr/nts131

Centers for Disease Control and Prevention. (2016a). Conducting trend analyses of YRBS data.

Centers for Disease Control and Prevention. (2016b). *Trends in Current Cigarette Smoking Among High School Students and Adults, United States, 1965-2014*. Retrieved from https://www.cdc.gov/tobacco/data_statistics/tables/trends/cig_smoking/index.htm

Clarke, T. C., Black, L. I., Stussman, B. J., Barnes, P. M., & Nahin, R. L. (2015). Trends in the use of complementary health approaches among adults: United States, 2002–2012. *National Health Statistics Reports*, (79), 1.

Cooke, M. E., Nasim, A., Cho, S. B., Kendler, K. S., Clark, S. L., & Dick, D. M. (2016). Predicting tobacco use across the first year of college. *American Journal of Health Behavior*, *40*(4), 484–495. https://doi.org/10.5993/AJHB.40.4.10

Creamer, M. R., Perry, C. L., Harrell, M. B., & Diamond, P. M. (2015). Trends in multiple tobacco product use among high school students. *Tobacco Regulatory Science*, *1*(3), 204–214. https://doi.org/10.18001/TRS.1.3.2

Doran, N., & Brikmanis, K. (2016). Expectancies for and use of e-cigarettes and hookah among young adult non-daily smokers. *Addictive Behaviors*, *60*, 154–159. https://doi.org/10.1016/j.addbeh.2016.04.008

Fish, L. J., Pollak, K. I., Scheuermann, T. S., Cox, L. S., Mathur, C., & Ahluwalia, J. S. (2015). Comparison of native light daily smokers and light daily smokers who were former heavy smokers. *Nicotine and Tobacco Research*, *17*(5), 546–551. https://doi.org/10.1093/ntr/ntu169

Fix, B. V., O'Connor, R. J., Vogl, L., Smith, D., Bansal-Travers, M., Conway, K. P., … Hyland, A. (2014). Patterns and correlates of polytobacco use in the United States over a decade: NSDUH 2002–2011. *Addictive Behaviors*, *39*(4), 768–781. https://doi.org/10.1016/j.addbeh.2013.12.015

Forman-Hoffman, V. L., Hedden, S. L., Miller, G. K., Brown, K., Teich, J., & Gfroerer, J. (2017). Trends in cigarette use, by serious psychological distress status in the United States, 1998–2013. *Addictive Behaviors*, *64*, 223–228. https://doi.org/10.1016/j.addbeh.2016.09.003

Gilpin, E. A. (2005). How effective are tobacco industry bar and club marketing efforts in reaching young adults? *Tobacco Control*, *14*(3), 186–192. https://doi.org/10.1136/tc.2004.009712

Gilreath, T. D., Leventhal, A., Barrington-Trimis, J. L., Unger, J. B., Cruz, T. B., Berhane, K., … McConnell, R. (2016). Patterns of alternative tobacco product use: emergence of hookah and e-cigarettes as preferred products amongst youth. *Journal of Adolescent Health*, *58*(2), 181–185. https://doi.org/10.1016/j.jadohealth.2015.10.001

Hu, S. S. (2016). Tobacco product use among adults—United States, 2013–2014. *MMWR. Morbidity and Mortality Weekly Report*, *65*.

Jamal, A., Homa, D. M., O'Connor, E., Babb, S. D., Caraballo, R. S., Singh, T., … King, B. A. (2015). Current cigarette smoking among adults—United States, 2005–2014. *MMWR Morb Mortal Wkly Rep*, *64*(44), 1233–1240.

Kim, H. J., Fay, M. P., Feuer, E. J., & Midthune, D. N. (2000). Permutation tests for joinpoint regression with applications to cancer rates. *Statistics in Medicine*, *19*(3), 335–351. https://doi.org/10.1002/(SICI)1097-0258(20000215)19:3<335::AID-SIM336>3.0.CO;2-Z

King, B. A., Alam, S., Promoff, G., Arrazola, R., & Dube, S. R. (2013). Awareness and ever-use of electronic cigarettes among u.s. Adults, 2010-2011. *Nicotine and Tobacco Research*, *15*(9), 1623–1627. https://doi.org/10.1093/ntr/ntt013

Li, X., Loukas, A., & Perry, C. L. (2018). Very light smoking and alternative tobacco use among college students. *Addictive Behaviors*, *81*, 22–25. https://doi.org/10.1016/j.addbeh.2018.01.038

Ling, P. M., & Glantz, S. A. (2002). Why and how the tobacco industry sells cigarettes to young adults: evidence from industry documents. *American Journal of Public Health*, *92*(6), 908–916. https://doi.org/10.2105/AJPH.92.6.908

Ling, P. M., & Glantz, S. A. (2004). Tobacco industry research on smoking cessation. Recapturing young adults and other recent quitters. *Journal of General Internal Medicine*, *19*(5 Pt 1), 419–426. https://doi.org/10.1111/j.1525-1497.2004.30358.x

Loukas, A., Batanova, M., Fernandez, A., & Agarwal, D. (2015). Changes in use of cigarettes and non-cigarette alternative products among college students. *Addictive Behaviors*, *49*, 46–51. https://doi.org/10.1016/j.addbeh.2015.05.005

Marynak, K. L., Gammon, D. G., King, B. A., Loomis, B. R., Fulmer, E. B., Wang, T. W., & Rogers, T. (2017). National and state trends in sales of cigarettes and e-cigarettes, U.S.,

2011–2015. *American Journal of Preventive Medicine*. https://doi.org/10.1016/j.amepre.2017.01.016

Maziak, W., Taleb, Z. B., Bahelah, R., Islam, F., Jaber, R., Auf, R., & Salloum, R. G. (2015). The global epidemiology of waterpipe smoking. *Tobacco Control*, *24*(Suppl 1), i3–i12. https://doi.org/10.1136/tobaccocontrol-2014-051903

McIntire, R. K., Macy, J. T., Seo, D.-C., Nelson, A. A., & Kolbe, L. J. (2014). Secondhand smoke exposure in cars and rooms: Trend comparisons among subpopulations of nonsmoking U.S. Middle and High School Students. *Nicotine and Tobacco Research*, *16*(6), 663–671. https://doi.org/10.1093/ntr/ntt207

McMillen, R. C., Gottlieb, M. A., Shaefer, R. M. W., Winickoff, J. P., & Klein, J. D. (2015). Trends in electronic cigarette use among U.S. adults: Use is increasing in both smokers and nonsmokers. *Nicotine and Tobacco Research*, *17*(10), 1195–1202. https://doi.org/10.1093/ntr/ntu213

Nasim, A., Khader, Y., Blank, M. D., Cobb, C. O., & Eissenberg, T. (2012). Trends in alternative tobacco use among light, moderate, and heavy smokers in adolescence, 1999–2009. *Addictive Behaviors*, *37*(7), 866–870. https://doi.org/10.1016/j.addbeh.2012.03.001

Nelson, D. E., Mowery, P., Asman, K., Pederson, L. L., O'Malley, P. M., Malarcher, A., … Pechacek, T. F. (2008). Long-term trends in adolescent and young adult smoking in the United States: Metapatterns and implications. *American Journal of Public Health*, *98*(5), 905–915. https://doi.org/10.2105/AJPH.2007.115931

Nguyen, Q. B., & Zhu, S.-H. (2009). Intermittent smokers who used to smoke daily: A preliminary study on smoking situations. *Nicotine and Tobacco Research*, *11*(2), 164–170. https://doi.org/10.1093/ntr/ntp012

Nollen, N. L., Ahluwalia, J. S., Lei, Y., Yu, Q., Scheuermann, T. S., & Mayo, M. S. (2016). Adult cigarette smokers at highest risk for concurrent alternative tobacco product use among a racially/ethnically and socioeconomically diverse sample. *Nicotine and Tobacco Research*, *18*(4), 386–394. https://doi.org/10.1093/ntr/ntv110

Perry, C. L., Pérez, A., Bluestein, M., Garza, N., Obinwa, U., Jackson, C., ... & Harrell, M. B. (2018). Youth or young adults: Which group is at highest risk for tobacco use onset? *Journal of Adolescent Health*. https://doi.org/10.1016/j.jadohealth.2018.04.011

Pierce, J. P., White, M. M., & Messer, K. (2009). Changing age-specific patterns of cigarette consumption in the United States, 1992-2002: Association with smoke-free homes and state-level tobacco control activity. *Nicotine and Tobacco Research*, *11*(2), 171–177. https://doi.org/10.1093/ntr/ntp014

Pinsker, E. A., Berg, C. J., Nehl, E. J., Prokhorov, A. V., Buchanan, T. S., & Ahluwalia, J. S. (2013). Intent to quit among daily and non-daily college student smokers. *Health Education Research*, *28*(2), 313–325. https://doi.org/10.1093/her/cys116

Ramo, D. E., Liu, H., & Prochaska, J. J. (2012). Tobacco and marijuana use among adolescents and young adults: A systematic review of their co-use. *Clinical Psychology Review*, *32*(2), 105–121. https://doi.org/10.1016/j.cpr.2011.12.002

Rath, J. M., Villanti, A. C., Abrams, D. B., & Vallone, D. M. (2012). Patterns of tobacco use and dual use in us young adults: The missing link between youth prevention and adult cessation. *Journal of Environmental and Public Health*, *2012*, 1–9. https://doi.org/10.1155/2012/679134

Richardson, A., Williams, V., Rath, J., Villanti, A. C., & Vallone, D. (2014). The next generation of users: Prevalence and longitudinal patterns of tobacco use among us young adults.

American Journal of Public Health, *104*(8), 1429–1436. https://doi.org/10.2105/AJPH.2013.301802

Ridner, S. L., Myers, J. A., Hahn, E. J., & Ciszewski, T. N. (2010). College students' exposure to tobacco marketing in nightclubs and bars. *Journal of American College Health*, *59*(3), 159–164. https://doi.org/10.1080/07448481.2010.483716

SAS. (2009). SAS User's Guide: Statistics, Release 9.1.

SAS Institute Inc. (2015). AS/STAT® 14.1 User's Guide. Cary, NC: SAS Institute Inc. SAS Institute Inc.

Schane, R. E., Glantz, S. A., & Ling, P. M. (2009). Nondaily and social smoking: An increasingly prevalent pattern. *Archives of Internal Medicine*, *169*(19). https://doi.org/10.1001/archinternmed.2009.315

Schauer, G. L., Berg, C. J., Kegler, M. C., Donovan, D. M., & Windle, M. (2015). Assessing the overlap between tobacco and marijuana: Trends in patterns of co-use of tobacco and marijuana in adults from 2003–2012. *Addictive Behaviors*, *49*, 26–32. https://doi.org/10.1016/j.addbeh.2015.05.012

Schauer, G. L., Malarcher, A. M., & Mowery, P. (2016). National trends in frequency and amount of nondaily smoking, and relation to quit attempts, 2000–2012. *Nicotine and Tobacco Research*, *18*(6), 1539–1544. https://doi.org/10.1093/ntr/ntv258

Singh, T., Arrazola, R. A., Corey, C. G., Husten, C. G., Neff, L. J., Homa, D. M., & King, B. A. (2016). Tobacco use among middle and high school students — United States, 2011–2015. *MMWR. Morbidity and Mortality Weekly Report*, *65*(14), 361–367. https://doi.org/10.15585/mmwr.mm6514a1

Statistical Research and Applications Branch, N. C. I. (2017). Joinpoint Regression Program, Version 4.5. 0.1.

Substance Abuse and Mental Health Services Administration. (2012). The NSDUH Report: Trends in Cigarette Use among Adolescents and Young Adults. Rockvill, MD. Retrieved from http://archive.samhsa.gov/data/2k12/NSDUH047/SR047CigaretteTrends2012.htm

Waters, K., Harris, K., Hall, S., Nazir, N., & Waigandt, A. (2006). Characteristics of social smoking among college students. *Journal of American College Health*, *55*(3), 133–139. https://doi.org/10.3200/JACH.55.3.133-139

CHAPTER FOUR (STUDY 2): ALTERNATIVE TOBACCO USE AND CIGARETTE SMOKING STATUS TRANSITIONS AMONG COLLEGE STUDENTS

Introduction

The prevalence of past 30-day cigarette smoking has been declining in the past 50 years and has reached record lows in recent years. Data from a nationally representative survey showed that the proportion of US adults who smoke cigarettes fell from 20.9% in 2005 to 15.5% in 2016 (Jamal et al., 2016, 2018). However, smoking at a light level has been increasing or remained relatively stable among some subpopulations. Among US adults, the proportion of daily smokers who smoked 1-9 cigarettes per day (cpd) increased from 2005 to 2014 and remained stable from 2014 to 2016 (Jamal et al., 2016, 2018). Prevalence of very light smoking among young adults is particularly high. According to Study One of this dissertation, from 2002 to 2015, the prevalence of very light smoking (i.e., smoked <= 5 cpd during the past 30 days) increased from 50.6% to 64.7% among young adult smokers.

Contemporaneous with the trends of cigarette use has been the frequent use of alternative tobacco products (ATPs) and the increasing concurrent use of cigarettes and ATP among US young adults. Although cigarettes remain the most consumed tobacco product, use of ATPs, including electronic cigarettes (e-cigarettes), cigars, and hookah has gained popularity particularly among young adults (Richardson, Williams, et al., 2014). According to results from the 2015 National Health Interview Survey, 4.3% of young adults aged 18-24 were current e-cigarette users, 4.2% were cigar/cigarillos/filtered little cigar users, 3.4% were pipe, water pipe

or hookah users, and 3.2% were current smokeless tobacco users (Phillips et al., 2017). Compared with other age groups young adults are more likely to use ATPs, especially emerging products such as hookah and e-cigarettes (Hu, 2016; Phillips et al., 2017). Young adults are likely to use ATPs on a non-daily basis, to report a lower level of consumption and to use at social events (Curry et al., 2007; Hammond, 2005; Hu, 2016; Song & Ling, 2011). Previous studies also showed that young adults have the highest rate of multiple tobacco product use (i.e., poly-tobacco use; concurrent use of $\geq$ 2 tobacco products) compared with other adult groups (Lee, Hebert, et al., 2014). Nationally representative data showed that 5.4% of young adults used more than one tobacco product in the past 30 days (Phillips et al., 2017) and most young adult multiple tobacco users have cigarettes as one component of their set of tobacco products (Kasza et al., 2017; Soneji et al., 2016).

Young adulthood (Arnett, 2005; Arnett, 2000) is a critical period in human development. In this period, tobacco use behaviors are still experimental and are variable regarding both frequency and intensity of use (Bonnie et al., 2015). The number of individuals initiating smoking at age 18 or older increased from 2002 to 2013 (Substance Abuse and Mental Health Services Administration, 2014), and about a third of adult ever tobacco users reported tobacco product initiation in young adulthood (Rath et al., 2012). Recent data indicate that the rate of tobacco initiations is greater during young adulthood than adolescence (Perry et al., 2018). Most young adult smokers either maintained a similar pattern of use or increased their smoking frequency across time (Caldeira et al., 2012; Cooke et al., 2016; White et al., 2009) and about forty percent of regular users reported progressing to regular use during young adulthood (Loukas et al., 2015; Rath et al., 2012). Tobacco use in young adulthood is linked to tobacco-related health outcomes across the life course (Caldeira et al., 2012; USDHHS, 2014). Moreover,

how tobacco use patterns change among young adults is related to how tobacco use evolves in the next few decades.

Previous studies have examined associations between cigarette smoking and alternative tobacco products use (e.g., smokeless tobacco, cigar, and hookah) among young adults. Current cigarette smokers are not only more likely than nonsmokers to have tried at least one ATP (King et al., 2013; McMillen et al., 2012), but are also at increased risk of current ATP use (Enofe et al., 2014). Very light smoking reflects a pattern of smoking in social situations (Schane et al., 2009; Waters et al., 2006) and has been associated with increased susceptibility to ATP use (Li et al., 2018).

Longitudinal studies have also examined the transition of tobacco use among young adults. Some studies focused on trajectories of cigarette smoking in young adulthood (Caldeira et al., 2012; Wetter et al., 2004; White et al., 2009). Results from these studies showed that over time most young adult smokers either maintained a similar pattern of use or increased their smoking frequency. Although daily smoking and heavy smoking are rare among young adults, they are relatively more stable than light and intermittent smoking. Several studies reported the relative risk of cigarette smoking for individuals who have never used alternative tobacco products compared with individuals who have ever used ATP (Barrington-Trimis et al., 2016; Doran, Godfrey, & Myers, 2015; Primack, Soneji, Stoolmiller, Fine, & Sargent, 2015; Soneji et al., 2017; Soneji, Sargent, Tanski, & Primack, 2015). Most of these studies have focused on examining one type of ATP on cigarette smoking. Results indicated that electronic cigarette use, hookah use and smokeless tobacco use are independently associated with elevated risk for cigarette initiation, current smoking, and progression to heavier smoking. Recent studies also investigated the dynamics of how young adults transition between different tobacco products

when they use more than one tobacco product (Cobb et al., 2015; Hair et al., 2018; Kaufman, Land, Parascandola, Augustson, & Backinger, 2015). However, few studies have examined the effect of alternative tobacco use on a variety of possible transitions in smoking status, such as from initial experimentation with cigarettes to very light smoking, to the development of heavier smoking, and/or to cessation.

Understanding transitions of smoking status and the effect of alternative tobacco use on transitions among college students is particularly important given that college students represent 35% to 40% of young adults (Snyder et al., 2016). Although college students are less likely to smoke heavily than their non-college-attending peers, they are at least equally likely to be light or intermittent smokers (White et al., 2009). The transition into and out of college poses unique developmental challenges for behavior change (Fromme et al., 2008), which puts college students at elevated risk for light and intermittent smoking and concurrent use of tobacco products. Previous studies have examined associations between cigarette smoking status and ATP use among college students (Li et al., 2018; Sutfin, McCoy, Morrell, Hoeppner, & Wolfson, 2013). However, longitudinal changes in smoking status among college students have not been explored. Also unknown is the effect of ATP use on the transitions of cigarette smoking status among college smokers. The present study extends existing research by examining longitudinal transitions of cigarette smoking status among college students across a two and half year period and current alternative tobacco use (use of the e-cigarette, hookah, and cigar) as a correlate of these transitions. Multistate Markov modeling was used to address three research questions: 1) How does a college student's smoking status change in 2.5 years? 2) How long do college students tend to stay in each smoking status before transitioning out of that status? 3) How does ATP use influence transitions of smoking status?

Methods

PARTICIPANTS

This study used data from six semi-annual waves of the Marketing and Promotions Across Colleges in Texas project (Project M-PACT), a rapid response, online survey assessing tobacco use behaviors (Loukas et al., 2016). A cohort of college students (n=5,482) aged 18-29 years were recruited to take the baseline (Wave 1) survey between Nov 2014 and Feb 2015. Five additional waves were collected at 6-month intervals with Wave 6 data collected from April to May 2017. Retention rates across the five follow-up waves ranged from 78% to 81%.

Young adult participants aged 18 to 25 (n=4806) who provided valid answers to smoking status questions at two or more waves were included in the analyses for this study. Over two third of participants took all waves. At baseline 63.7% were female. The average age of participants at baseline was 20.2 years (*SD*=1.84), and about 61.9% were 18 to 20 years old. About 93.3% of the participants went to four-year colleges. Regarding race/ethnicity, 35.2% of the participants were non-Hispanic white, 31.1% were Hispanic/Latino, 8.0% were African-American/Black, 18.0% were Asian, and 7.6% reported another race/ethnicity or reported two or more races/ethnicities. See Table 4.1 for demographic descriptive at each wave.

PROCEDURE

Project MPACT (Marketing and Promotions Across Colleges in Texas) recruited students aged 18-29 from 24 2- and 4-year colleges in five counties surrounding four target cities (Austin, Dallas/Fort Worth, Houston, and San Antonio). To ensure recruitment of adequate numbers of students from each college, only schools with a minimum enrollment of 2500 students were

considered for inclusion, and 2-year colleges were required to have students enrolled in vocational/ technical programs. A total of 65 colleges were identified in 4 target cities (Austin, Dallas/Fort Worth, Houston, and San Antonio). Three colleges of each type were selected from each city, for a total of 6 per city, to comprise a total of 24 colleges (12 2-year colleges with vocational programs and 12 4-year colleges).

Overall, 13,714 students were eligible to participate in the study. Eligible students attending the 24 colleges were recruited to participate in the online survey via email invitation, which described the purpose of the study and included a link to an eligibility survey. Email addresses were obtained through public records requests, and project staff emailed invitations to students at 15 colleges. The remaining nine colleges did not provide student addresses to project staff, and instead the colleges emailed students a participation invitation on the project's behalf. Eligible students who wished to participate in the study provided informed consent and then completed the online survey. A total of 5482 college students completed the baseline (Wave 1) survey from November 2014 to February 2015. The rate of participation is 40%, which is similar to other online studies of college students (Berg et al., 2015). The baseline participants were followed and retook the survey every six months thereafter for two and half years. In each wave, participants were compensated with an e-gift card (raised from $10 at Wave 1-2 to $20 at Wave 3-6) and entered into a drawing to win one of twenty $50 e-gift cards.

The original study included 18-29 years old undergraduates, however, those who were 26-29 years-old were restricted to lifetime tobacco users. Lifetime tobacco use was defined by having ever smoked at least 100 cigarettes, or at least 20 cigars, or having ever used smokeless/spit/chewing tobacco at least 20 times. The current study aims to examine transitions in smoking and initiation is unlikely to occur after the age of 26. Therefore, only young adults

aged 18 to 25 who provided valid answers to smoking status questions in both Wave 1 survey and at least one follow-up survey were included in this study (n=4806).

MEASURES

Socio-demographic variables

Sex, age group, race/ethnicity and college type were included as covariates in the analyses. A race/ethnicity variable was created to indicate whether a participant was non-Hispanic White or ethnic minority. Age was analyzed as two groups, younger (18-20 years old) versus older (21-25 years old) at Wave 1. The reference groups were male, older, ethnic minority and two-year college students.

Observation time

Arbitrary timepoints were set for each wave based on the survey distribution with six-month intervals: 0 = Wave 1 or baseline, 1 = Wave 2 i.e., 0.5 year after baseline, 2 = Wave 3 i.e., 1 year after baseline, 3 = Wave 4 i.e., 1.5 years after baseline, 4 = Wave 5 i.e., 2 years after baseline, and 5 = Wave 6 i.e., 2.5 years after baseline.

Smoking status

Three questions were used to assess smoking status. Lifetime/ever cigarette smoking status was dichotomized into never smoker vs. ever smoker. Current smoking status was examined by asking a) “on how many of the past 30 days did you smoke cigarettes?” and b) “on the days you smoked, how many cigarettes did you usually smoke each day?”. The first current smoking question regarded current frequency and the other regarded current quantity. Based on prior research (Husten, 2009; Pierce et al., 2009), the total monthly number of cigarettes was

obtained by multiplying current frequency and current quantity, and then the average cpd was computed as total monthly cigarettes divided by 30. Four categories of smoking status were examined: 1 = never smoker (have never used even one cigarette), 2 = non-current smoker (have ever used cigarettes but never used in the past 30 days), 3 = very light smoker ($\leq$ 5 cpd in the past 30 days) and 4 = heavier smoker (> 5 cpd in the past 30 days).

Current alternative tobacco products (ATP) use

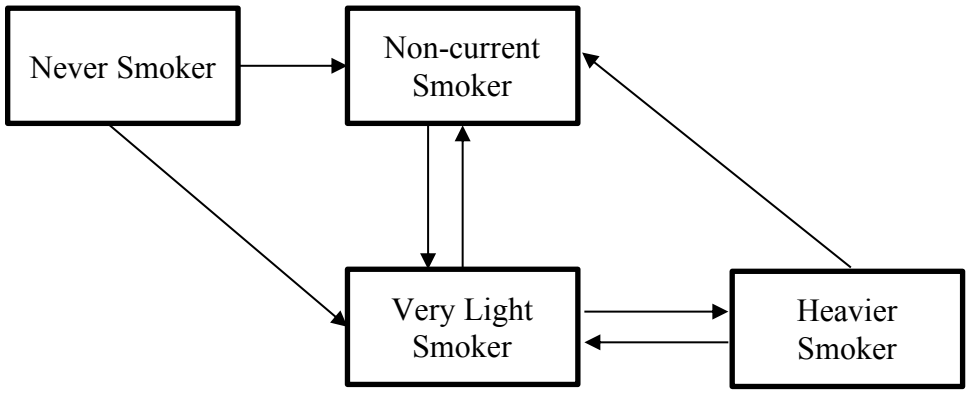
Current (past 30-day) use of alternative tobacco products, including e-cigarette, cigar, hookah and smokeless tobacco, was assessed with one item for each product, adapted from the Youth Tobacco Survey (Starr et al., 2005) and the Population Assessment of Tobacco and Health (PATH) Survey (National Institutes of Health, 2015). The current e-cigarette use question asked "During the past 30 days, have you used any ENDS product…?" For all other products (i.e., cigar products, hookah, and smokeless tobacco) the question asked "during the past 30 days, how many did you use/smoke [product]"? Students who responded 1 or more days to any of these items were considered current ATP users. Baseline current ATP use (0 = did not use any ATP in the past 30 days at Wave 1, 1 = used ATP in the past 30 days at Wave 1) was examined as a main covariate.

DATA ANALYSIS

Wave 1 to Wave 6 observations were stacked into a long dataset. Smoking status was investigated and categorized into four groups (1 = never smoker, 2 = non-current smoker, 3 = very light smoker and 4 = heavier smoker) at baseline (t = 0) and at least one of the follow-ups (i.e., 0.5, 1, 1.5, 2, and 2.5 years).

Markov modeling was used to simultaneously analyze transitions into and out of different smoking statuses over two and half years. The model used all valid data from respondents with two or more observations to estimate the transition intensity matrix, which defines the possible transitions between states (See Figure 4.1). One-way transitions were allowed from never smoker into non-current smoker and very light smoker. Once someone has used cigarettes, there is no way to transition back to never smoker. The probability of direct transitions from never smoker to heavier smoker and non-current smokers to heavier smoker were set to be 0 because changes of these two types were extremely rare in our dataset.

Figure 4.1: Structure of allowed transitions for the multi-state Markov model.



Various models were considered to examine transitions of smoking status among college students, especially longitudinal analysis that handles changes of status. For example, survival analysis (also called time-to-event analysis) could be used to estimate probabilities of tobacco use initiation (Cooper, Loukas, Case, Marti, & Perry, 2018); however, it does not simultaneously model transitions into and out of current smoking status. Growth curve and growth mixture modeling could be used to investigate trajectories of smoking status over time, but these models work better if the smoking status is a continuous variable (Caldeira et al., 2012; Lenk et al.,

2017). The Markov model approach was finally selected because it provides a useful way to describe changes between a variety of states over time. Markov model, named for Andrey Markov, is a mathematical system that represents a process in which individuals move through a series of states in continuous time (Cox & Miller, 1996; Kaplan, 2008; Langeheine & van de Pol, 2002).

All analyses were conducted in R 3.3 with package *msm* (Jackson, 2011, 2018). This package allows multi-state models for panel data (data from arbitrary observed timepoints), data from exactly-observed transition times, data with latent states, absorbed states (such as death) and censored states, or a mixture of these schemes (Jackson, 2018). For this study, simple (or manifest) continuous time Markov models were selected to examine changes in the four categories of smoking status over two and half years. Unlike hidden Markov models, in which states of the Markov chain are not directly observed, simple Markov models assume that the measure of a categorical variable is perfectly reliable and that all parameters can be obtained directly from manifest categorical responses (Bartolucci, Farcomeni, & Pennoni, 2013; Kaplan, 2008). Unlike discrete state Markov models, which assume states can only change at one of the discrete time and remain stable between adjacent timepoints, the continuous time model allows transitions to occur at any times along observed time intervals (Mhoon, Chan, Del Junco, & Vernon, 2010). The *msm* package models were also used to examine the effects of ATP use on transitions in smoking.

An initialization matrix (see Table 4.2) was used to get the maximum likelihood estimates of the transition intensity matrix (see Table 4.3). The transition intensity matrix was then used to calculate the transition probabilities matrix within each given time, and the mean sojourn time in each state (i.e., the estimated duration of time remaining in a certain smoking

status) (Hair et al., 2018; Jackson, 2011). A model with no covariate was first fit to the data, followed by five separate models examining only one covariate at a time (sex, age group, race/ethnicity, college type, and alternative tobacco use at Wave 1) (Mhoon et al., 2010). Log-likelihood ratio goodness-of-fit tests (Hair et al., 2018; Jackson, 2011) revealed that only sex and baseline alternative tobacco use significantly improved the model fit ($p < 0.01$). The model with both covariates was then tested and showed the best fit to the data (see Table 4.4). A full model was used to estimate the probability matrix of allowed transitions between smoking status, the mean sojourn times of each status and the hazard ratio of alternative tobacco products use at baseline for each transition (Hair et al., 2018; Jackson, 2011).

Results

DESCRIPTIVE OF SMOKING STATUS AND ALTERNATIVE TOBACCO USE

Table 4.1 shows the distribution of smoking status and two alternative tobacco use statuses (baseline ATP use and current ATP use) across 2.5 years. At Wave 1 (t = 0), 54.2% of the 4,806 participants were never smokers, 26.4% were non-current users, 17.7% were very light smokers, and only 1.7% were heavier smokers. Over time, the proportion of never smoking status decreased from 54.2% at Wave 1 to 46.9% at Wave 6 and the prevalence of non-current smoking status increased from 26.4% at Wave 1 to 37.3% at Wave 6. The prevalence of very light smoking status had a small-scale decrease but remained fairly constant across two and half years. The proportion of heavier smoking in the past 30 days was relatively low and was consistent at about 1.5% at all six waves. The prevalence of current ATP use declined from

28.7% at baseline to 19.9% at Wave 6. To examine the effect of ATP use on smoking status, baseline current ATP use was investigated in Markov models.

PROBABILITY OF TRANSITIONING BETWEEN SMOKING STATUS OVER TIME

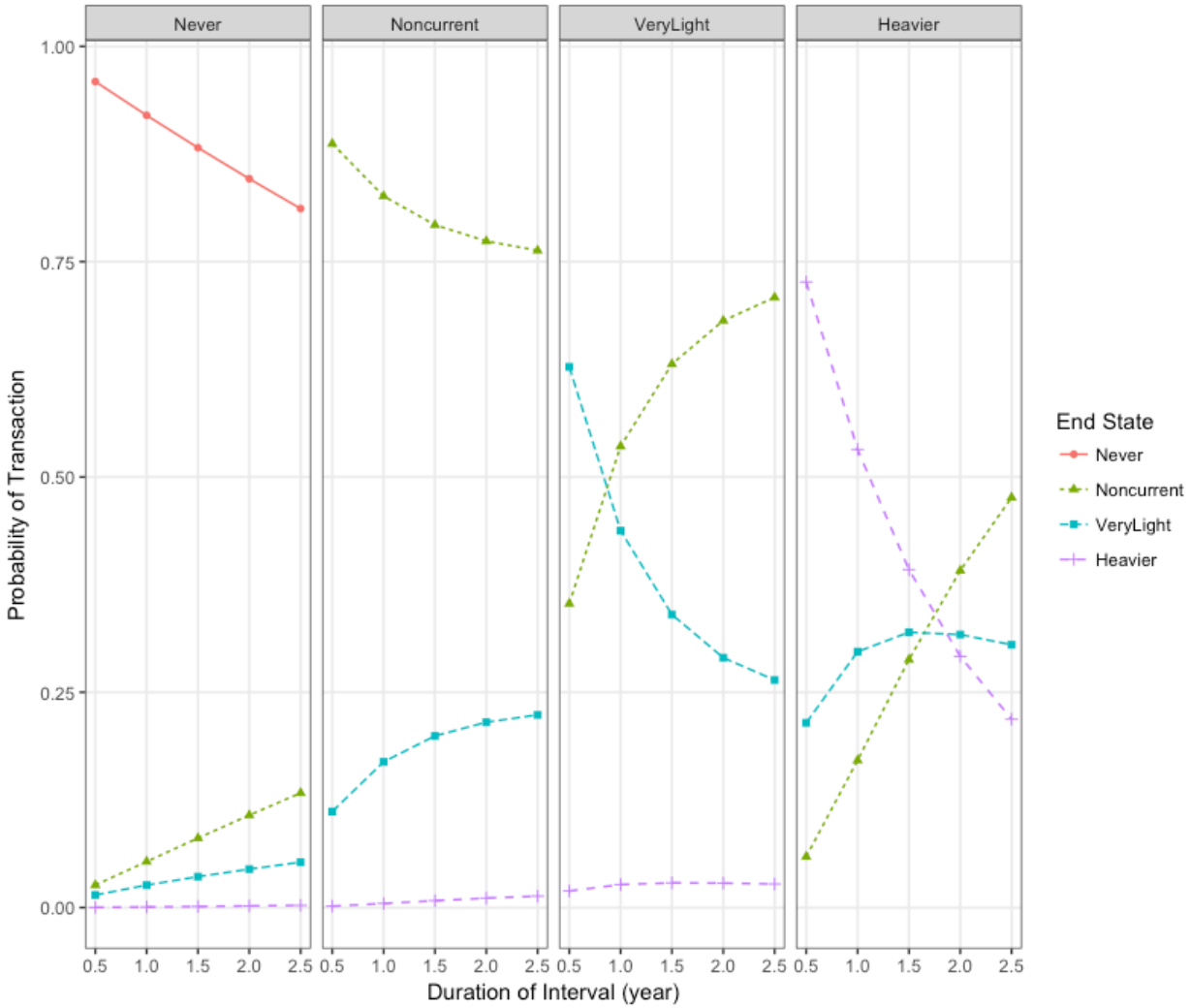
Before examining time of process as an indicator of transition in a Markov model, the author summarized the multi-state data using a frequency table of transitions between consecutive states using all observations (Table 4.5). The table included the number of times an observation of state (in row) occurred followed by another state (in column). The wave-by-wave transition rates between all possible smoking statuses were computed and listed in Table 4.6.

Using a continuous-time Markov model, transition probabilities between all pairs of smoking status were estimated without effects of covariates across time intervals between 0.5 and 2.5 years. Table 4.7 and Figure 4.2 illustrated the changes of transition probabilities over time. Each panel represents a different starting smoking status (such as very light smoking), and the series represents the conditional probability that a participant will be in a smoking status (such as non-current smoking) at the end of the time interval. Confidence intervals of model estimates were not graphed in Figure 4.2 but provided in Table 4.7.

According to Figure 4.2 and Table 4.7, the probabilities of remaining in a smoking status decreased over time for all four smoking statuses. However, never smoking and non-current smoking patterns were fairly stable. Across a 6-month period, 95.9% of participants with never smoker as start state remained in never smoking status and about 88.7% of non-current smokers remained in abstinence from cigarettes during the past 30 days. Even over a 2.5-year interval, more than 80% of never smokers and about three quarters of non-current smokers remained in their starting smoking status. The probabilities of remaining in the two current smoking statuses

decreased drastically over time. Although with a 6-month interval, 62.8% of very light smokers ended up with maintaining very light smoking and 72.6% of heavier smokers maintained heavier smoking, at the end of the 2.5-year time period, the transition probabilities decreased to 26.4% and 21.9% respectively.

Figure 4.2: Transition probabilities across two and half years (with a six-month interval).



Note: Each panel represents a different starting smoking status, and the series represent the probability of being in each of the four smoking statuses at a certain time conditioned on that starting smoking status. Matrix of model estimates including confidence intervals is provided in Table 4.7.

The probability of moving from another smoking status to very light smoking status increased; however, the increasing rate diminished over time. For example, the probability of transitioning from non-current smoker to very light smoker increased from 11.1% across a 6-month interval to about 20% across a 1.5-year interval, then increased to 22.4% at the end of the 2.5-year interval. The probability of transitioning from heavier smoker to very light smoker increased drastically from the 21.4% across a 6-month interval to 29.7% across a 1-year interval, then the probability of such transition remained at around 30% over a time period longer than 1 year.

Figure 4.2 and Table 4.7 also highlighted the differences between the short-term and long-term transitions for two current smoking statuses – very light smoking and heavier smoking. Within one year, very light smokers were more likely to maintain their smoking status than to transition to non-current smoker. However, after one year, the most probable state for very light smokers was changing to non-current status other than maintaining very light smoking. During shorter intervals (i.e., up to 1.5 years after Wave 1), heavier smokers are most likely to maintain smoking more than 5 cigarettes per day, and least likely to stop smoking during the past 30 days. However, during longer intervals (i.e., more than 2 years after Wave 1), heavier smokers are most likely to transition to non-current smokers followed by change to very light smoking and least likely to maintain a heavier smoking level.

AVERAGE TIME IN EACH SMOKING STATUS

The average time that participants stay in each smoking status (i.e., sojourn time) was estimated at the mean of all covariates. Estimated sojourn time was approximately 12 years for never smoking (95% CI: 10.9-13.2); 3.3 years for non-current smoking (95% CI: 3.0–3.6); 1 year

for very light smoking (95% CI: 0.9–1.1); and 1.5 years for heavier smoking (95% CI: 1.2–2.1). The estimated time in state was much longer for never smokers than any of the other smoking groups. Non-current smoking status also lasted relatively longer. The longer sojourn time for noncurrent smoker (including never smoker and non-current smokers) implies that noncurrent smoking is fairly stable among college students. Most students who have not tried cigarettes or who just wanted to experiment with cigarettes would not use cigarettes in long stretches. However, if participating college students used alternative tobacco at baseline, their sojourn time for noncurrent smoking state (including never and non-current smoking) will be greatly shortened (see Table 4.8). The sojourn times was comparatively short in current smoking especially among very light smokers. The findings suggested that the average time for college students to maintain very light smoking status was about one year and they may transition out of that state after a year.

EFFECTS OF ALTERNATIVE TOBACCO PRODUCT USE AT WAVE 1

To examine the effect of current alternative tobacco product use on the transition of smoking status among college students, the hazard ratios of baseline (Wave 1) current ATP use were computed. The hazard ratios indicate that ATP users at Wave 1 had higher risk of making instantaneous transitions from never smokers to non-current smokers, from never smoker to very light smokers and from non-current smokers to very light smokers. ATP use was not associated with transitioning between very light smoking and heavier smoking, but it was significantly related to decreased odds of transitioning from very light smokers to non-current smokers (see Table 4.9). Effect of ATP use can also be investigated by comparing the sojourn time in each smoking status among ATP users at Wave 1 to those who were not ATP users at Wave 1 (Table

4.8). The sojourn times of never smoking were 15 years or above for both male and female college students if they did not use ATP at baseline, and the duration shortened drastically to 5.3 for females and 4.5 for males if they used ATP at baseline.

In addition, the author examined how transition probabilities differed by sex. The findings indicated that most transitions between smoking status did not differ for male and female college students. However, female college students were less likely to transition from non-current smoking status to very light smoking status (Hazard ratio = 0.78, 95% CI: 0.67–0.90). Another way to demonstrate the gender difference is by examining how sojourn times in each smoking status vary by sex. Compared with males, female college students spent a longer time in non-current smoking status before transitioning into very light smoking, regardless of whether they used ATP at Wave 1 (Table 4.8).

Discussion

The present study aimed to examine young adults' transition of smoking status in a sample collected from Texas colleges. Continuous-time Markov modeling was applied to generate the transition probabilities of the four-state categorical smoking status using longitudinal data across 2.5 years. The inclusion of covariates with Markov models allows for the hazard ratio test to determine the effect of alternative tobacco product use on the transition of smoking status. Overall, we found that the transitions of smoking status among college students were associated with starting smoking status, the duration of the interval, sex and the use of alternative tobacco products.

Our findings were consistent with previous reports on smoking initiation and smoking patterns among young adults. More than half of college students in our sample have never tried

cigarettes at Wave 1. However, of those who started as never smokers, 81.6% maintained never smoking, and the rest initiated cigarette smoking at the end of a 2.5-year time interval. This finding confirms that experimentation with cigarettes has expanded from adolescence to young adulthood (Hu, 2016). The number of individuals initiating smoking at age 18 or older increased (Perry et al., 2018; Substance Abuse and Mental Health Services Administration, 2014), and about a third of adult ever tobacco users reported tobacco product initiation in young adulthood (Rath et al., 2012). The results also confirm that most current cigarette smokers among college students used no more than 5 cpd, and heavier smoking and nicotine dependence were rare among college students (Caldeira et al., 2012).

Before taking the time intervals and covariates into consideration, the sojourn time (i.e., the average time in each smoking status) can be examined to understand the stability of different smoking behaviors among college students. Those who were never smokers stayed without initiating cigarette for about 12 years before changing into a different smoking state, while those non-current smokers who tried cigarettes but did not smoke in the past 30 days remained so for approximately 3.3 years before transitioning. Our findings indicated that without the effect of other factors, noncurrent smoking statuses were relatively stable over the 4 years of college. In contrast, current smokers changed their use patterns during the college year. The sojourn time is 1 year for very light smoking and 1.5 years for heaver smoking. The shorter sojourn of very light smoking among college students confirms that very light smokers change their smoking patterns more frequently compared to non-smokers and heavy smokers (White et al., 2009). Although college students tend to move out of very light smoking after a year, more evidence is needed to conclude the stability of this smoking behavior across time.

The present study extended previous research on cigarette smoking among young adults by examining the transitions into and out of very light smoking in different time intervals ranging from a half year to two and half years. White, Bray, Fleming, and Catalano (2009) followed a large cohort of high school seniors into early adulthood. They found that more than three-quarters of heavy smokers remained heavy smokers 2 years later, but only 31% of light smokers remained light smokers. They concluded that very light smoking was less stable than noncurrent smoking and heavier smoking. In a trajectory analysis, Caldeira et al. (2012) examined trajectories of cigarette smoking patterns in college students over 4 years and depicted the smoking trajectories based on smoking frequency (number of smoking days) and smoking quantity (number of cigarettes per smoking day). They found that during the college years, most student smokers either maintained a similar pattern of use or increased their smoking frequency, and only 3.2% decreased their smoking frequency. They also reported that a substantial percentage of light and intermittent smokers maintain a low smoking level after 1- to 4-year follow-up. Our findings confirm a number of earlier reports on the transition of very light smoking among college students across time. Although most of very light smokers among college students transition out of current smoking after 2.5 years, about a third of very light smokers either maintained their smoking level (26.4%) or increased their smoking level (2.7%). In addition, many college students transitioned into very light smoking state from non-current smoking (22.4%) or from heavier smoking (30.5%) at the end of the 2.5-year observation time. By using Markov models, this study allowed multiple transitions during a time interval and further investigated the transition probabilities by duration of observation time. We found that the transition of smoking behaviors depended on both the starting smoking status and observation time. The length of the time interval of interest is associated with the probabilities

that an individual stays in or moves out of a smoking status. This is especially true for those two current smoking statuses – very light smoking and heavier smoking. Although the probabilities of maintaining very light smoking status decreased over time and the probabilities of transition from other smoking status into very light smoking increased over time. Among college students, very light smoking is more prevalent and more stable than heavier smokers over time.

To better illustrate the dynamics of smoking status among college students, this present study examined the effects of both demographic and behavioral covariates simultaneously in a four-state continuous time Markov model. Most college student smokers are very light smokers and are likely to use alternative tobacco products along with cigarettes (Cooke et al., 2016). Many believe that alternative tobacco products have significantly lower health risks than cigarettes, can facilitate smoking reduction or cessation, or can be used where smoking is not allowed (Berg, Haardoerfer, Escoffery, Zheng, & Kegler, 2015; Choi, Fabian, Mottey, Corbett, & Forster, 2012; Etter, 2010). However, any form of tobacco use is harmful, and no empirical evidence can support the perception that alternative tobacco products can help smokers quit successfully. Continuous time Markov model was used to investigate transition of among dual use and exclusive use of combustible tobacco products and ENDS in youth and young adults (Hair et al., 2018). A novel contribution of this study is the utilization of Markov model to examine the effect of alternative tobacco use on a variety of possible transitions in smoking status. In line with prior research on tobacco use among young adults, our results showed that ATP use was associated with elevated risk for cigarette initiation, and current smoking (Barrington-Trimis et al., 2016; Doran et al., 2015; Primack et al., 2015; Soneji et al., 2017, 2015). Our findings also indicated that ATP use was significantly related to decreased odds of transitioning from very light smokers to non-current smokers. Instead of being motivated to quit

or cut down on smoking (Sutfin et al., 2013), very light smokers might use ATPs for coping, improving affect or for socialization purposes (Doran & Brikmanis, 2016). Although some studies reported that ATP use is related to progressing to heavier smoking (Doran et al., 2015), results of this study showed that ATP use was not associated with transitioning between very light smoking and heavier smoking.

In conclusion, very light smoking is the critical smoking pattern among college students, and the transition of very lights smoking among college students presents both opportunities and challenges to tobacco control researchers and educators. The convergence of the transition probabilities over time across use states indicates that although very light smoking is not as stable as never smoking and non-current smoking across two and half years among college students, it is more stable than heavier smoking. On one hand, tobacco prevention program could be more efficient by focusing on the shorter sojourn time of very lights smoking and the higher probability of transitioning to non-current smoking. On the other hand, research is needed to focus on sustained very light smokers across time. Moreover, the concurrent use of ATP among very light smokers is popular, and is an obstacle of the smoking cessation effort.

Limitation

Although continuous-time Markov modeling is useful in characterizing the transition of smoking status among college students, the method of this study has some limitations. First, the author follows the current convention of categorizing smokers; however, by this definition heavier smoking (using more than 5 cigarettes per day) is very rare among college students. The small panel of heavier smokers brought issues to model estimations such as confidence intervals with wide ranges for transitions in and out of heavier smoking. Second, although most of our

participants took all 6 waves of the survey, current smokers (especially heavier smokers) had tendencies to participate in fewer waves. This usually does not violate the assumption of non-informative observation time. However, the model estimations will be biased if a participant's decision to skip a wave is related to their transition of smoking status. Third, the study didn't consider the issue of participants transitions out of college across the two and half years of the study. In Wave 1, all participates at were enrolled as college students. As time passed, some of them graduated or left school. Education status could change the dynamic of smoking status among young adults. Fourth, the ability to examine the effect of covariates on transition probabilities was limited for Markov models with more than two states (Mhoon et al., 2010). Most of the published continuous-time Markov research only provides analyses using one covariate at a time. Although one study mentioned the use of four simultaneous covariates, this study reported the estimated effect of just one covariate (Hair et al., 2018). The r package *msm* is a very useful tool for multi-state Markov modeling, but it has a high rate of convergence issues when examining the influence of more than two simultaneous covariates on transition probabilities. The author included two covariates in the same model. However, previous studies have indicated that more psychosocial factors, such as change of motives (Darlow & Lobel, 2012), and subjective experience with different types of ATPs (Do et al., 2018) are related to the transition of smoking status.

Implications

Overall, college students in young adulthood are experiencing many life transitions and the trajectories of their health-related behaviors are complex. Use of a longitudinal dataset collected by Project M-PACT and multi-state continuous-time Markov modeling provides a

unique opportunity to examine transitions of tobacco use with both shorter and longer time interval up to 2.5 years. Moreover, using this approach, one can assess the influence of more than one covariate on transition rates between states simultaneously. The present study examined the transitions of smoking status among college students and the effect of alternative tobacco use on these transitions. The findings indicated that current smoking status, including both very light smoking and heavier smoking, is not stable among college students. ATP use might impede quitting from very light smoking. These findings highlight the need to identify priorities for tobacco control programs and policies among college students. Health care providers and educators should caution smokers, especially very light smokers, against ATP use. Future studies need to consider the dynamics of cigarette smoking and tobacco use among young adults under a socio-ecological framework. Users of different tobacco products have distinct psychographic characteristics, and more studies are needed to examine the effect of the most popular noncombustible ATPs such as emerging electronic cigarettes on tobacco use transitions.

Table 4.1: Demographic and tobacco use distributions of young adults, MPACT Wave 1 (n=4806) – Wave 6 (n=4169), age range at baseline is 18-25 years.

	W1 (n=4806)	W2 (n=4109)	W3 (n=4115)	W4 (n=4207)	W5 (n=4053)	W6 (n=4169)
Current Age (Mean (SD))	20.6 (1.82)	21.1 (1.82)	21.5 (1.82)	22.0 (1.82)	22.5 (1.81)	23.0 (1.81)
W1 Age Group (%)						
18-20 year	62.1	62.4	62.1	62.3	62.7	62.8
21-25 year	37.9	37.6	37.9	37.7	37.3	37.2
Sex (%)						
Female	64.1	64.2	64.5	64.4	35.0	64.7
Male	35.9	35.8	35.5	35.6	65.0	35.3
Race/Ethnicity (%)						
White	35.2	35.1	35.0	34.4	35.2	34.8
Minorities	64.8	64.9	65.0	65.6	64.8	65.2
School Type (%)						
Four-year	93.5	93.8	94.0	93.7	94.0	93.9
Two-year	6.5	6.2	6.0	6.3	6.0	6.1
Current Smoking Status (%)						
Never	54.2	53.0	50.6	49.3	48.1	46.9
Non-current	26.4	30.4	32.7	34.4	36.5	37.3
Very light	17.7	15.1	15.3	14.8	13.9	14.3
Heavier	1.7	1.5	1.4	1.5	1.5	1.5
W1 ATP Use (%)	28.7	27.7	27.7	27.8	27.5	27.9
Current ATP Use (%)	28.7	26.5	24.0	22.8	19.8	19.9

Note: ATP = alternative tobacco product use.

Table 4.2: The matrix of allowed transitions used to begin the modeling process.

	Never	Non-current	Very Light	Heavier
Never	-0.2	0.1	0.1	0
Non-current	0	-0.2	0.2	0
Very Light	0	0.1	-0.2	0.1
Heavier	0	0.1	0.1	-0.2

Table 4.3: The crude initial intensity matrix.

	Never	Non-current	Very Light	Heavier
Never	-0.035	0.023	0.012	0
Non-current	0	-0.117	0.117	0
Very Light	0	0.308	-0.329	0.021
Heavier	0	0.031	0.227	-0.258

Table 4.4: Log-likelihood ratio tests for model selection.

Model	-2 log LR	df	*p*
No Covariates	14389.94	-	-
School Type	3.52	7	0.834
Race	11.19	7	0.130
Age Group	18.00	7	0.012
Sex	61.93	7	<.001
W1 ATP use	224.98	7	<.001
Sex + W1 ATP use[1]	44.69	7	<.001

Note: ATP = alternative tobacco product use.
[1]Model with both covariates compared with the model with W1 ATP use as covariate.

Table 4.5: Frequency table of transitions between consecutive states using all observations.

	End State			
Start State	Never	Non-current	Very Light	Heavier
Never	10240	262	143	3
Non-current	0	5701	837	14
Very Light	0	1101	1967	75
Heavier	0	11	81	218

Table 4.6: Transition rates

		Transition Rate			
		Never	Non-current	Very Light	Heavier
W1-W2	Never	0.95	0.03	0.02	0.00
	Non-current	0.00	0.86	0.14	0.00
	Very Light	0.00	0.37	0.60	0.02
	Heavier	0.00	0.00	0.28	0.72
W2-W3	Never	0.97	0.02	0.01	0.00
	Non-current	0.00	0.86	0.14	0.00
	Very Light	0.00	0.34	0.64	0.02
	Heavier	0.00	0.04	0.24	0.72
W3-W4	Never	0.97	0.02	0.01	0.00
	Non-current	0.00	0.88	0.12	0.00
	Very Light	0.00	0.34	0.64	0.02
	Heavier	0.00	0.02	0.21	0.77
W4-W5	Never	0.97	0.02	0.01	0.00
	Non-current	0.00	0.88	0.11	0.00
	Very Light	0.00	0.34	0.63	0.03
	Heavier	0.00	0.06	0.26	0.69
W5-W6	Never	0.98	0.01	0.01	0.00
	Non-current	0.00	0.88	0.12	0.00
	Very Light	0.00	0.34	0.64	0.02
	Heavier	0.00	0.07	0.28	0.66

Table 4.7: Transition probabilities across multiple time intervals.

		End State			
Time Interval	Start State	Never	Non-current	Very Light	Heavier
0.5 year	Never	0.959[0.955 to 0.963]	0.026[0.023 to 0.030]	0.015[0.012 to 0.017]	--
0.5 year	Non-current	--	0.887[0.878 to 0.894]	0.111[0.104 to 0.120]	0.002[0.001 to 0.002]
0.5 year	Very Light	--	0.353[0.333 to 0.374]	0.628[0.608 to 0.648]	0.019[0.010 to 0.025]
0.5 year	Heavier	--	0.059[0.046 to 0.631]	0.214[0.149 to 0.274]	0.726[0.218 to 0.782]
1 year	Never	0.920[0.911 to 0.927]	0.053[0.048 to 0.060]	0.026[0.023 to 0.030]	0.001[0 to 0.001]
1 year	Non-current	--	0.826[0.814 to 0.838]	0.169[0.158 to 0.181]	0.005[0.002 to 0.006]
1 year	Very Light	--	0.536[0.512 to 0.563]	0.438[0.413 to 0.462]	0.027[0.009 to 0.034]
1 year	Heavier	--	0.171[0.141 to 0.745]	0.297[0.202 to 0.360]	0.532[0.045 to 0.611]
1.5 years	Never	0.882[0.870 to 0.892]	0.081[0.073 to 0.089]	0.036[0.032 to 0.041]	0.001[0 to 0.002]
1.5 years	Non-current	--	0.793[0.779 to 0.807]	0.199[0.187 to 0.213]	0.008[0.002 to 0.010]
1.5 years	Very Light	--	0.631[0.609 to 0.659]	0.340[0.319 to 0.362]	0.029[0.005 to 0.037]
1.5 years	Heavier	--	0.288[0.238 to 0.778]	0.320[0.214 to 0.365]	0.392[0.007 to 0.489]
2 years	Never	0.846[0.831 to 0.860]	0.107[0.097 to 0.119]	0.045[0.040 to 0.051]	0.002[0.001 to 0.003]
2 years	Non-current	--	0.774[0.759 to 0.790]	0.215[0.201 to 0.230]	0.011[0.003 to 0.014]
2 years	Very Light	--	0.681[0.663 to 0.710]	0.290[0.270 to 0.309]	0.028[0.004 to 0.037]
2 years	Heavier	--	0.391[0.340 to 0.771]	0.317[0.224 to 0.351]	0.292[0.003 to 0.372]
2.5 years	Never	0.812[0.795 to 0.826]	0.133[0.122 to 0.147]	0.053[0.048 to 0.059]	0.003[0.001 to 0.003]
2.5 years	Non-current	--	0.763[0.747 to 0.781]	0.224[0.209 to 0.240]	0.013[0.003 to 0.017]
2.5 years	Very Light	--	0.708[0.689 to 0.740]	0.264[0.247 to 0.283]	0.027[0.003 to 0.036]
2.5 years	Heavier	--	0.476[0.415 to 0.771]	0.305[0.225 to 0.329]	0.219[0.003 to 0.304]

Table 4.8: Sojourn times estimated at for all participants, female non-alternative tobacco product (ATP) users, female ATP users, male non-ATP users and male ATP users.

	State	Estimates	SE	95% Upper	95% Lower
All	Never	12.0	0.6	10.9	13.2
	Non-current	3.3	0.1	3.0	3.6
	Very Light	1.0	0.0	0.9	1.1
	Heavier	1.5	0.2	1.2	2.1
Female Non-ATP	Never	17.7	1.2	15.5	20.2
	Non-current	4.3	0.3	3.8	4.8
	Very Light	0.9	0.0	0.8	1.0
	Heavier	1.4	0.3	0.9	2.1
Female ATP	Never	5.3	0.6	4.3	6.6
	Non-current	2.3	0.1	2.0	2.6
	Very Light	1.0	0.1	0.9	1.1
	Heavier	1.3	0.2	1.0	1.9
Male Non-ATP	Never	15.0	1.3	12.6	17.9
	Non-current	3.3	0.2	2.9	3.8
	Very Light	1.0	0.1	0.9	1.1
	Heavier	1.9	0.4	1.2	3.0
Male ATP	Never	4.5	0.5	3.6	5.6
	Non-current	1.8	0.1	1.6	2.0
	Very Light	1.1	0.1	1.0	1.2
	Heavier	1.8	0.3	1.3	2.5

Table 4.9: Hazard ratios [95% CI] depicting the effect of alternative tobacco product (ATP) use at wave 1 on overall transition intensities.

	End State		
Start State	Non-current	Very Light	Heavier
Never	**3.61** [2.581-5.048]	**2.94** [1.838-4.690]	-
Non-current	-	**1.86** [1.605-2.151]	-
Very Light	**0.87** [0.765-0.994]	-	1.33 [0.840-2.094]
Heavier	0.41 [NA]	1.06 [0.657-1.697]	-

Significant hazard ratios ($p < 0.05$) are bolded.

Reference

Arnett, J. J. (2000). Emerging adulthood: A theory of development from the late teens through the twenties. *American Psychologist*, *55*(5), 469–480. https://doi.org/10.1037//0003-066X.55.5.469

Arnett, J. J. (2005). The developmental context of substance use in emerging adulthood. *Journal of Drug Issues*, *35*(2), 235–254. https://doi.org/10.1177/002204260503500202

Barrington-Trimis, J. L., Urman, R., Berhane, K., Unger, J. B., Cruz, T. B., Pentz, M. A., … McConnell, R. (2016). E-cigarettes and future cigarette use. *PEDIATRICS*, *138*(1), e20160379–e20160379. https://doi.org/10.1542/peds.2016-0379

Bartolucci, F., Farcomeni, A., & Pennoni, F. (2013). *Latent Markov models for longitudinal data*. Boca Raton, FL: CRC Press, Taylor & Francis Group.

Berg, C. J., Haardoerfer, R., Escoffery, C., Zheng, P., & Kegler, M. (2015). Cigarette users' interest in using or switching to electronic nicotine delivery systems for smokeless tobacco for harm reduction, cessation, or novelty: A cross-sectional survey of US adults. *Nicotine and Tobacco Research*, *17*(2), 245–255. https://doi.org/10.1093/ntr/ntu103

Bonnie, R. J., Stratton, K., & Kwan, L. Y. (Eds.). (2015). Patterns of tobacco use by adolescents and young adults. In *Public health implications of raising the minimum age of legal access to tobacco products*. Washington, D.C: The National Academies Press.

Caldeira, K. M., O'Grady, K. E., Garnier-Dykstra, L. M., Vincent, K. B., Pickworth, W. B., & Arria, A. M. (2012). Cigarette smoking among college students: longitudinal trajectories and health outcomes. *Nicotine and Tobacco Research*, *14*(7), 777–785. https://doi.org/10.1093/ntr/nts131

Choi, K., Fabian, L., Mottey, N., Corbett, A., & Forster, J. (2012). Young adults' favorable perceptions of snus, dissolvable tobacco products, and electronic cigarettes: findings from a focus group study. *American Journal of Public Health*, *102*(11), 2088–2093. https://doi.org/10.2105/AJPH.2011.300525

Cobb, C. O., Villanti, A. C., Graham, A. L., Pearson, J. L., Glasser, A. M., Rath, J. M., … Niaura, R. (2015). Markov modeling to estimate the population impact of emerging tobacco products: A proof-of-concept study. *Tobacco Regulatory Science*, *1*(2), 129–141. https://doi.org/10.18001/TRS.1.2.3

Cooke, M. E., Nasim, A., Cho, S. B., Kendler, K. S., Clark, S. L., & Dick, D. M. (2016). Predicting tobacco use across the first year of college. *American Journal of Health Behavior*, *40*(4), 484–495. https://doi.org/10.5993/AJHB.40.4.10

Cooper, M., Loukas, A., Case, K. R., Marti, C. N., & Perry, C. L. (2018). A longitudinal study of risk perceptions and e-cigarette initiation among college students: Interactions with smoking status. *Drug and Alcohol Dependence*, *186*, 257–263. https://doi.org/10.1016/j.drugalcdep.2017.11.027

Cox, D. R., & Miller, H. D. (1996). *The theory of stochastic processes*. London: Chapman & Hall.

Curry, S. J., Sporer, A. K., Pugach, O., Campbell, R. T., & Emery, S. (2007). Use of tobacco cessation treatments among young adult smokers: 2005 National Health Interview Survey. *American Journal of Public Health*, *97*(8), 1464–1469. https://doi.org/10.2105/AJPH.2006.103788

Darlow, S., & Lobel, M. (2012). Smoking behavior and motivational flexibility in light and heavy smokers. *Addictive Behaviors*, *37*(5), 668–673. https://doi.org/10.1016/j.addbeh.2012.02.001

Do, E. K., Prom-Wormley, E. C., Fuemmeler, B. F., Dick, D. M., Kendler, K. S., & Maes, H. H. (2018). Associations between initial subjective experiences with tobacco and self-reported recent use in young adulthood. *Substance Use & Misuse*, 1–8. https://doi.org/10.1080/10826084.2018.1473435

Doran, N., Godfrey, K. M., & Myers, M. G. (2015). Hookah use predicts cigarette smoking progression among college smokers. *Nicotine and Tobacco Research*, *17*(11), 1347–1353. https://doi.org/10.1093/ntr/ntu343

Enofe, N., Berg, C. J., & Nehl, E. J. (2014). Alternative tobacco use among college students: Who is at highest risk? *American Journal of Health Behavior*, *38*(2), 180–189. https://doi.org/10.5993/AJHB.38.2.3

Etter, J. F. (2010). Electronic cigarettes: A survey of users. *BMC Public Health*, *10*(1). https://doi.org/10.1186/1471-2458-10-231

Fromme, K., Corbin, W. R., & Kruse, M. I. (2008). Behavioral risks during the transition from high school to college. *Developmental Psychology*, *44*(5), 1497–1504. https://doi.org/10.1037/a0012614

Hair, E. C., Romberg, A. R., Niaura, R., Abrams, D. B., Bennett, M. A., Xiao, H., … Vallone, D. (2018). Longitudinal tobacco use transitions among adolescents and young adults: 2014–2016. *Nicotine and Tobacco Research*. https://doi.org/10.1093/ntr/ntx285

Hammond, D. (2005). Smoking behaviour among young adults: Beyond youth prevention. *Tobacco Control*, *14*(3), 181–185. https://doi.org/10.1136/tc.2004.009621

Hu, S. S. (2016). Tobacco product use among adults—United States, 2013–2014. *MMWR. Morbidity and Mortality Weekly Report*, *65*.

Husten, C. G. (2009). How should we define light or intermittent smoking? Does it matter? *Nicotine and Tobacco Research*, *11*(2), 111–121. https://doi.org/10.1093/ntr/ntp010

Jackson, C. (2011). Multi-state models for panel data: The *msm* package for R. *Journal of Statistical Software*, *38*(8). https://doi.org/10.18637/jss.v038.i08

Jackson, C. (2018). Package 'msm.'

Jamal, A., Brian, K. A., Neff, L. J., Whitmill, J., Babb, S. D., & Graffunder, C. M. (2016). Current cigarette smoking among adults—United States, 2005–2015. *MMWR. Morbidity and Mortality Weekly Report*, *65*(44), 1205–1211.

Jamal, A., Phillips, E., Gentzke, A. S., Homa, D. M., Babb, S. D., King, B. A., & Neff, L. J. (2018). Current cigarette smoking among adults — United States, 2016. *MMWR. Morbidity and Mortality Weekly Report*, *67*(2), 53–59. https://doi.org/10.15585/mmwr.mm6702a1

Kaplan, D. (2008). An overview of Markov chain methods for the study of stage-sequential developmental processes. *Developmental Psychology*, *44*(2), 457–467. https://doi.org/10.1037/0012-1649.44.2.457

Kasza, K. A., Ambrose, B. K., Conway, K. P., Borek, N., Taylor, K., Goniewicz, M. L., … Hyland, A. J. (2017). Tobacco Product use by adults and youths in the United States in 2013 and 2014. *New England Journal of Medicine*, *376*(4), 342–353. https://doi.org/10.1056/NEJMsa1607538

Kaufman, A. R., Land, S., Parascandola, M., Augustson, E., & Backinger, C. L. (2015). Tobacco use transitions in the United States: The National Longitudinal Study of Adolescent Health. *Preventive Medicine*, *81*, 251–257. https://doi.org/10.1016/j.ypmed.2015.08.026

King, B. A., Alam, S., Promoff, G., Arrazola, R., & Dube, S. R. (2013). Awareness and ever-use of electronic cigarettes among U.S. adults, 2010-2011. *Nicotine and Tobacco Research*, *15*(9), 1623–1627. https://doi.org/10.1093/ntr/ntt013

Langeheine, R., & van de Pol, F. (2002). Latent Markov Chains. In J. A. Hagenaars & A. L. McCutcheon (Eds.), *Applied Latent Class Analysis* (pp. 304–342). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511499531.012

Lee, Y. O., Hebert, C. J., Nonnemaker, J. M., & Kim, A. E. (2014). Multiple tobacco product use among adults in the United States: Cigarettes, cigars, electronic cigarettes, hookah, smokeless tobacco, and snus. *Preventive Medicine*, *62*, 14–19. https://doi.org/10.1016/j.ypmed.2014.01.014

Lenk, K. M., Erickson, D. J., & Forster, J. L. (2017). Trajectories of cigarette smoking from teens to young adulthood: 2000 to 2013. *American Journal of Health Promotion*, 089011711769635. https://doi.org/10.1177/0890117117696358

Li, X., Loukas, A., & Perry, C. L. (2018). Very light smoking and alternative tobacco use among college students. *Addictive Behaviors*, *81*, 22–25. https://doi.org/10.1016/j.addbeh.2018.01.038

Loukas, A., Batanova, M., Fernandez, A., & Agarwal, D. (2015). Changes in use of cigarettes and non-cigarette alternative products among college students. *Addictive Behaviors*, *49*, 46–51. https://doi.org/10.1016/j.addbeh.2015.05.005

Loukas, A., Chow, S., Pasch, K. E., Li, X., Hinds III, J. T., Marti, C. N., … Perry, C. L. (2016). College students' polytobacco use, cigarette cessation, and dependence. *American Journal of Health Behavior*, *40*(4), 514–522. https://doi.org/10.5993/AJHB.40.4.13

McMillen, R., Maduka, J., & Winickoff, J. (2012). Use of emerging tobacco products in the United States. *Journal of Environmental and Public Health*, *2012*, 1–8. https://doi.org/10.1155/2012/989474

Mhoon, K. B., Chan, W., Del Junco, D. J., & Vernon, S. W. (2010). A continuous-time Markov chain approach analyzing the stages of change construct from a health promotion intervention. *JP Journal of Biostatistics*, *4*(3), 213–226.

Perry, C. L., Pérez, A., Bluestein, M., Garza, N., Obinwa, U., Jackson, C., ... & Harrell, M. B. (2018). Youth or young adults: Which group is at highest risk for tobacco use onset? *Journal of Adolescent Health*. https://doi.org/10.1016/j.jadohealth.2018.04.011

Phillips, E., Wang, T. W., Husten, C. G., Corey, C. G., Apelberg, B. J., Jamal, A., … King, B. A. (2017). Tobacco product use among adults — United States, 2015. *MMWR. Morbidity and Mortality Weekly Report*, *66*(44), 1209–1215. https://doi.org/10.15585/mmwr.mm6644a2

Pierce, J. P., White, M. M., & Messer, K. (2009). Changing age-specific patterns of cigarette consumption in the United States, 1992-2002: Association with smoke-free homes and state-level tobacco control activity. *Nicotine and Tobacco Research*, *11*(2), 171–177. https://doi.org/10.1093/ntr/ntp014

Primack, B. A., Soneji, S., Stoolmiller, M., Fine, M. J., & Sargent, J. D. (2015). Progression to traditional cigarette smoking after electronic cigarette use among US adolescents and young adults. *JAMA Pediatrics*, *169*(11), 1018. https://doi.org/10.1001/jamapediatrics.2015.1742

Rath, J. M., Villanti, A. C., Abrams, D. B., & Vallone, D. M. (2012). patterns of tobacco use and dual use in US young adults: The missing link between youth prevention

and adult cessation. *Journal of Environmental and Public Health*, *2012*, 1–9. https://doi.org/10.1155/2012/679134

Richardson, A., Williams, V., Rath, J., Villanti, A. C., & Vallone, D. (2014). The next generation of users: Prevalence and longitudinal patterns of tobacco use among US young adults. *American Journal of Public Health*, *104*(8), 1429–1436. https://doi.org/10.2105/AJPH.2013.301802

Schane, R. E., Glantz, S. A., & Ling, P. M. (2009). Nondaily and social smoking: An increasingly prevalent pattern. *Archives of Internal Medicine*, *169*(19). https://doi.org/10.1001/archinternmed.2009.315

Snyder, T., de Brey, C., & Dillow, S. (2016). *Digest of Education Statistics, 2014*. Retrieved from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2016006

Soneji, S., Barrington-Trimis, J. L., Wills, T. A., Leventhal, A. M., Unger, J. B., Gibson, L. A., … Sargent, J. D. (2017). Association between initial use of e-cigarettes and subsequent cigarette smoking among adolescents and young adults: A systematic review and meta-analysis. *JAMA Pediatrics*, *171*(8), 788. https://doi.org/10.1001/jamapediatrics.2017.1488

Soneji, S., Sargent, J. D., Tanski, S. E., & Primack, B. A. (2015). Associations between initial water pipe tobacco smoking and snus use and subsequent cigarette smoking: results from a longitudinal study of US adolescents and young adults. *JAMA Pediatrics*, *169*(2), 129. https://doi.org/10.1001/jamapediatrics.2014.2697

Soneji, S., Sargent, J., & Tanski, S. (2016). Multiple tobacco product use among US adolescents and young adults. *Tobacco Control*, *25*(2), 174–180. https://doi.org/10.1136/tobaccocontrol-2014-051638

Song, A. V., & Ling, P. M. (2011). Social smoking among young adults: Investigation of intentions and attempts to quit. *American Journal of Public Health*, *101*(7), 1291–1296. https://doi.org/10.2105/AJPH.2010.300012

Substance Abuse and Mental Health Services Administration. (2014). Results from the 2013 National Survey on Drug Use and Health: Summary of national findings. Rockvill, MD. Retrieved from https://www.samhsa.gov/data/sites/default/files/NSDUHresultsPDFWHTML2013/Web/NSDUHresults2013.pdf

Sutfin, E. L., McCoy, T. P., Morrell, H. E., Hoeppner, B. B., & Wolfson, M. (2013). Electronic cigarette use by college students. *Drug and Alcohol Dependence*, *131*(3), 214–221. https://doi.org/10.1016/j.drugalcdep.2013.05.001

Waters, K., Harris, K., Hall, S., Nazir, N., & Waigandt, A. (2006). Characteristics of social smoking among college students. *Journal of American College Health*, *55*(3), 133–139. https://doi.org/10.3200/JACH.55.3.133-139

Wetter, D. W., Kenford, S. L., Welsch, S. K., Smith, S. S., Fouladi, R. T., Fiore, M. C., & Baker, T. B. (2004). Prevalence and predictors of transitions in smoking behavior among college students. *Health Psychology*, *23*(2), 168–177. https://doi.org/10.1037/0278-6133.23.2.168

White, H. R., Bray, B. C., Fleming, C. B., & Catalano, R. F. (2009). Transitions into and out of light and intermittent smoking during emerging adulthood. *Nicotine and Tobacco Research*, *11*(2), 211–219. https://doi.org/10.1093/ntr/ntn017

CHAPTER FIVE: CONCLUSION

Although smoking rates continue to decline in the general population, emerging patterns of tobacco use, including light and intermittent smoking, alternative tobacco use, and multiple tobacco use, remain particularly prevalent among young adults. Current trends and transitions of tobacco use among young adults might result in a cohort effect for prevalence of tobacco use in the future (Nelson et al., 2008). The US Surgeon General's report of 2012 highlighted the importance of reducing young adults' initiation and use of tobacco products (US Department of Health and Human Services, 2012). However, the trends and transitions of the most popular smoking pattern, i.e., very light smoking, has not been fully explored. What is also needed is the investigation of the protective factors and risk factors that might affect the prevalence and progress of this behavior. The purpose of this dissertation is to explore the trends and transitions of very light smoking (no more than 5 cpd during the past 30 days) among young adults (age 18-25). In addition, the two studies of this dissertation investigated demographic and behavioral correlates, particularly alternative tobacco use, of trends and transitions of very light smoking among young adults.

To examine the trends of very light smoking and their association with sociodemographic and behavioral covariates, this study utilized 14 years of widely used public data to obtain nationally representative estimates from 2002 to 2015. Joinpoint analyses showed that among young adults the prevalence of very light smoking remained stable for almost ten years before the decline in the most recent 5 years. Among young

adult ever smokers, prevalence of very light smoking increased in general and in most subpopulations from 2002 to 2010 and then remained stable since 2010. Different trends of tobacco-related behaviors may reflect implementation of public policies and the effectiveness of population-level interventions, such as tobacco tax increase and smoking ban in public (USDHHS, 2014).

Trends of very light smoking vary in different subgroups of young adults. The general decline in very light smoking among young adults masks the different trends in certain tobacco use groups and demographic subpopulations. Across time, very light smoking has been increasing significantly among ever smokers who were male, not enrolled in college, non-Hispanic Black, non-Hispanic White, those who had less than high school education, those who used to be daily smokers and those who initiated smoking before 18 years of age. In addition, a significant linear increase occurred between 2002 and 2015 for the prevalence of very light smoking among young adults who have smoked cigarettes during the past 30 days. Aside from the effectiveness of policies and intervention programs in different subpopulations, other factors such as smoking motives and depression might contribute to the different trends of very light smoking in different subgroups (Audrain-McGovern et al., 2011; Bakhshaie et al., 2015; Forman-Hoffman et al., 2017). Future research needs to take these factors into consideration when examining trends of very light smoking in different subpopulations among young adults.

Young adulthood is an important developmental period for health behaviors. Although most young adult smokers are very light smokers, they may progress into

regular or heavier smokers and impact future trends of tobacco use. To examine the transitions of smoking statuses among young adults, continuous-time Markov modeling was applied to generate the transition probabilities of the four-state categorical smoking status using longitudinal data across 2.5 years (from November 2014 to May 2017). More than a quarter of very light smokers maintained their smoking level across 2.5 years among college students. The findings also indicated that the probability of maintaining a current smoking status changed over time. With a shorter time period, most very light smokers and heavier smokers maintained their start smoking status. However, across a longer time interval, the transition probabilities decreased to 26.4% and 21.9%, respectively. Our findings indicated that very light smoking is as stable as heavier smoking across 2.5 years although probabilities of transition into and out of this smoking status changed from time to time.

One contribution of this dissertation is associating alternative tobacco use with the trends and transition of very light smoking among young adults. Our findings indicated that the prevalence of alternative tobacco use among very light smokers continued to increase from 2002 to 2015 while the prevalence showed a decreasing trend among heavier smokers since 2010. The results from the Markov model with alternative tobacco use as a covariate showed that alternative tobacco use was significantly related to increased odds of transitioning from non-smoker to smoker and decreased odds of transitioning from very light smoker to noncurrent smoker. In other words, use alternative tobacco products accelerates the process of initiating cigarettes smoking and hinders the

process of quitting or reducing cigarette consumption among young adults. Alternative tobacco products, especially e-cigarettes, have become more and more popular among young adults. Tobacco companies targeted their marketing efforts to young adults and promoted these products as "healthier" alternatives that can facilitate smoking reduction and cessation. Our results raise alarm that public health efforts should prevent young adults from using alternative tobacco products. A deeper investigation into the trends of nicotine exposure among very light smoker is warranted.

In addition to filling gaps in our understanding of young adults' increasingly complex tobacco use trends and trajectories, the two studies of this dissertation also make methodological contributions to tobacco research. Unlike prior studies using national data that focus on pairwise comparison or linear trend tests between different time points, this study examined long-term smoking trends with a series of linear and polynomial models. The joinpoint package was used to obtain the change point of a nonlinear trend. Using a continuous-time Markov model, transition probabilities between all pairs of smoking status were estimated with effects of covariates across time intervals between 0.5 and 2.5 years. The studies integrate both variable-based analysis and person-centered analysis (Muthen & Muthen, 2000). Variable-centered approaches are used to examine differences between subgroups and associations among study variables, whereas person-centered approaches are used to examine variability in individual trajectories and transitions across time.

The studies have limitations. Some limitations are due to measures such as the set of variables measuring smoking and tobacco use behaviors. As light and intermittent smoking and alternative tobacco use have become more and more prevalent, traditional measurement of smoking status and definitions of light smoking may not be appropriate to study contemporary tobacco use patterns. Future research is needed to distinguish tobacco use groups and smoking patterns among young adults. Limitations of this dissertation are also related to procedures such as the methodological changes of NSDUH. These methodological changes might contribute to the significant increase or decrease in a trend or a break in a trend. Moreover, the tobacco policies and intervention programs in different geographical regions may also bias the trends of very light smoking. More studies are needed to examine methodological problems, policy changes in different geographical regions and other potential effect modifiers that were beyond the scope of this investigation. When generalizing the results of transition of smoking status, one should keep in mind that participants of project MPACT were recruited from 24 colleges in Texas and then followed up for two and half years. It is unknown whether the transition of smoking status is the same for college students and other young adults. Longitudinal research with national representative samples of young adults is needed to confirm our findings and to examine the potential effect of college enrollment. Limitations are also related to statistical models such as the limited capability of including more than two covariates in the Markov model. Models and algorithms need to be developed to include more covariates, to examine trends and transitions under a socio-

ecological frame work, and to better illustrate whether the trends and transitions persist across different subgroups of the population.

Very light smoking is still the most prevalent tobacco use behavior among young adults. Prevalence and progression of very light smoking is important for the trends of tobacco use in the next decades. In order to fulfil the tobacco-related objective of Healthy people 2020, targeted surveillance and cessation efforts toward young adults are warranted. Very light smoking reflects a pattern of smoking in social situations and has been associated with increased susceptibility to ATP use. Prevention programs need to be tailored to young adults in terms of their distinct tobacco use patterns. Health education programs, together with local, state, and federal regulation of alternative tobacco products, could prevent tobacco initiation, intervene in progression, facilitate cessation, and further reduce overall tobacco use.

REFERENCES

Ackerson, L. K., & Viswanath, K. (2009). Communication inequalities, social determinants, and intermittent smoking in the 2003 Health Information National Trends Survey. *Preventing Chronic Disease*, *6*(2), A40.

Agaku, I. T., & Alpert, H. R. (2016). Trends in annual sales and current use of cigarettes, cigars, roll-your-own tobacco, pipes, and smokeless tobacco among US adults, 2002–2012. *Tobacco Control*, *25*(4), 451–457. https://doi.org/10.1136/tobaccocontrol-2014-052125

Akl, E. A., Gaddam, S., Gunukula, S. K., Honeine, R., Jaoude, P. A., & Irani, J. (2010). The effects of waterpipe tobacco smoking on health outcomes: a systematic review. *International Journal of Epidemiology*, *39*(3), 834–857. https://doi.org/10.1093/ije/dyq002

Al-Delaimy, W. K., Pierce, J. P., Messer, K., White, M. M., Trinidad, D. R., & Gilpin, E. A. (2007). The California Tobacco Control Program's effect on adult smokers: (2) Daily cigarette consumption levels. *Tobacco Control*, *16*(2), 91–95. https://doi.org/10.1136/tc.2006.017061

American Lung Association. (2011). Trends in tobacco use. *Washington, DC: American Lung Association*.

Amrock, S. M., & Weitzman, M. (2015). Alternative tobacco products as a second front in the war on tobacco. *JAMA*, *314*(14), 1507. https://doi.org/10.1001/jama.2015.11394

An, L. C., Berg, C. J., Klatt, C. M., Perry, C. L., Thomas, J. L., Luo, X., … Ahluwalia, J. S. (2009). Symptoms of cough and shortness of breath among occasional young adult smokers. *Nicotine and Tobacco Research*, *11*(2), 126–133. https://doi.org/10.1093/ntr/ntp015

Arnett, J. J. (2000). Emerging adulthood: A theory of development from the late teens through the twenties. *American Psychologist*, *55*(5), 469–480. https://doi.org/10.1037//0003-066X.55.5.469

Arnett, J. J. (2005). The developmental context of substance use in emerging adulthood. *Journal of Drug Issues*, *35*(2), 235–254. https://doi.org/10.1177/002204260503500202

Audrain-McGovern, J., Rodriguez, D., Rodgers, K., & Cuevas, J. (2011). Declining alternative reinforcers link depression to young adult smoking: Depression, alternative reinforcers and smoking. *Addiction*, *106*(1), 178–187. https://doi.org/10.1111/j.1360-0443.2010.03113.x

Ayanian, J. Z. (1999). Perceived risks of heart disease and cancer among cigarette smokers. *JAMA*, *281*(11), 1019. https://doi.org/10.1001/jama.281.11.1019

Backinger, C. L., Fagan, P., O'Connell, M. E., Grana, R., Lawrence, D., Bishop, J. A., & Gibson, J. T. (2008). Use of other tobacco products among U.S. adult cigarette smokers: Prevalence, trends and correlates. *Addictive Behaviors*, *33*(3), 472–489. https://doi.org/10.1016/j.addbeh.2007.10.009

Baker, F. (2000). Health risks associated with cigar smoking. *JAMA*, *284*(6), 735. https://doi.org/10.1001/jama.284.6.735

Bakhshaie, J., Zvolensky, M. J., & Goodwin, R. D. (2015). Cigarette smoking and the onset and persistence of depression among adults in the United States: 1994–2005. *Comprehensive Psychiatry*, *60*, 142–148. https://doi.org/10.1016/j.comppsych.2014.10.012

Barnett, T. E., Smith, T., He, Y., Soule, E. K., Curbow, B. A., Tomar, S. L., & McCarty, C. (2013). Evidence of emerging hookah use among university students: a cross-sectional comparison between hookah and cigarette use. *BMC Public Health*, *13*(1). https://doi.org/10.1186/1471-2458-13-302

Barrington-Trimis, J. L., Urman, R., Berhane, K., Unger, J. B., Cruz, T. B., Pentz, M. A., … McConnell, R. (2016). E-cigarettes and future cigarette use. *PEDIATRICS*, *138*(1), e20160379–e20160379. https://doi.org/10.1542/peds.2016-0379

Bartolucci, F., Farcomeni, A., & Pennoni, F. (2013). *Latent Markov models for longitudinal data*. Boca Raton, FL: CRC Press, Taylor & Francis Group.

Berg, C. J., Cox, L. S., Choi, W. S., Mayo, M. S., Krebill, R., Bronars, C. A., & Ahluwalia, J. S. (2012). Assessment of depression among African American light smokers. *Journal of Health Psychology*, *17*(2), 197–206. https://doi.org/10.1177/1359105311414953

Berg, C. J., Haardoerfer, R., Escoffery, C., Zheng, P., & Kegler, M. (2015). Cigarette users' interest in using or switching to electronic nicotine delivery systems for

smokeless tobacco for harm reduction, cessation, or novelty: A cross-sectional survey of US adults. *Nicotine and Tobacco Research*, *17*(2), 245–255. https://doi.org/10.1093/ntr/ntu103

Berg, C. J., Lust, K. A., Sanem, J. R., Kirch, M. A., Rudie, M., Ehlinger, E., … An, L. C. (2009). Smoker self-identification versus recent smoking among college students. *American Journal of Preventive Medicine*, *36*(4), 333–336. https://doi.org/10.1016/j.amepre.2008.11.010

Berg, Carla J, Klatt, C. M., Thomas, J. L., Ahluwalia, J. S., & An, L. C. (2009). The relationship of field of study to current smoking status among college students. *College Student Journal*, *43*(3), 744.

Biener, L., & Hargraves, J. L. (2015). A longitudinal study of electronic cigarette use among a population-based sample of adult smokers: Association with smoking cessation and motivation to quit. *Nicotine and Tobacco Research*, *17*(2), 127–133. https://doi.org/10.1093/ntr/ntu200

Biener, Lois, McCausland, K., Curry, L., & Cullen, J. (2011). Prevalence of trial of snus products among adult smokers. *American Journal of Public Health*, *101*(10), 1874–1876. https://doi.org/10.2105/AJPH.2010.200097

Bjartveit, K., & Tverdal, A. (2005). Health consequences of smoking 1-4 cigarettes per day. *Tobacco Control*, *14*(5), 315–320. https://doi.org/10.1136/tc.2005.011932

Boffetta, P., Hecht, S., Gray, N., Gupta, P., & Straif, K. (2008). Smokeless tobacco and cancer. *The Lancet Oncology*, *9*(7), 667–675. https://doi.org/10.1016/S1470-2045(08)70173-6

Bondy, S. J., Victor, J. C., & Diemert, L. M. (2009). Origin and use of the 100 cigarette criterion in tobacco surveys. *Tobacco Control*, *18*(4), 317–323. https://doi.org/10.1136/tc.2008.027276

Bondy, S. J., Victor, J. C., Diemert, L. M., Mecredy, G. C., Chaiton, M., Brown, K. S., … Schwartz, R. (2013). Transitions in smoking status over time in a population-based panel study of smokers. *Nicotine and Tobacco Research*, *15*(7), 1201–1210. https://doi.org/10.1093/ntr/nts259

Bonnie, R. J., Stratton, K., & Kwan, L. Y. (Eds.). (2015). Patterns of tobacco use by adolescents and young adults. In *Public health implications of raising the minimum age of legal access to tobacco products*. Washington, D.C: The National Academies Press.

Boulos, D. N., Loffredo, C. A., El Setouhy, M., Abdel-Aziz, F., Israel, E., & Mohamed, M. K. (2009). Nondaily, light daily, and moderate-to-heavy cigarette smokers in a rural area of Egypt: A population-based survey. *Nicotine and Tobacco Research*, *11*(2), 134–138. https://doi.org/10.1093/ntr/ntp016

Breslau, N., Schultz, L. R., Johnson, E. O., Peterson, E. L., & Davis, G. C. (2005). Smoking and the risk of suicidal behavior: A prospective study of a community

sample. *Archives of General Psychiatry*, *62*(3), 328. https://doi.org/10.1001/archpsyc.62.3.328

Brown, A. E., Carpenter, M. J., & Sutfin, E. L. (2011). Occasional smoking in college: Who, what, when and why? *Addictive Behaviors*, *36*(12), 1199–1204. https://doi.org/10.1016/j.addbeh.2011.07.024

Butler, K. M., Ickes, M. J., Rayens, M. K., Wiggins, A. T., & Hahn, E. J. (2016). Polytobacco use among college students. *Nicotine and Tobacco Research*, *18*(2), 163–169. https://doi.org/10.1093/ntr/ntv056

Cabriales, J. A., Suro Maldonado, B., & Cooper, T. V. (2016). Smoking transitions in a sample of Hispanic daily light and intermittent smokers. *Addictive Behaviors*, *62*, 42–46. https://doi.org/10.1016/j.addbeh.2016.06.009

Caldeira, K. M., O'Grady, K. E., Garnier-Dykstra, L. M., Vincent, K. B., Pickworth, W. B., & Arria, A. M. (2012). Cigarette smoking among college students: longitudinal trajectories and health outcomes. *Nicotine and Tobacco Research*, *14*(7), 777–785. https://doi.org/10.1093/ntr/nts131

Center for Behavioral Health Statistics and Quality. (2015). *Behavioral health trends in the United States: results from the 2014 National Survey on Drug Use and Health*. Retrieved from Center for Behavioral Health Statistics and Quality

Centers for Disease Control and Prevention. (2016a). Conducting trend analyses of YRBS data.

Centers for Disease Control and Prevention. (2016b). *Trends in Current Cigarette Smoking Among High School Students and Adults, United States, 1965-2014*. Retrieved from https://www.cdc.gov/tobacco/data_statistics/tables/trends/cig_smoking/index.htm

Centers for Disease Control and Prevention. (2013). Vital signs: current cigarette smoking among adults aged ≥ 18 years with mental illness-United States, 2009-2011. *MMWR. Morbidity and Mortality Weekly Report*, *62*(5), 81.

Chassin, L., Curran, P. J., Presson, C. C., Sherman, S. J., & Wirth, R. (2009). Developmental trajectories of cigarette smoking from adolescence to adulthood. *Phenotypes and Endophenotypes: Foundations for Genetic Studies of Nicotine Use and Dependence (Tobacco Control Monograph No. 20). US Department of Health and Human Services, NIH, National Cancer Institute: NIH Publication*, (09–6366), 189–244.

Chassin, L., Presson, C. C., Pitts, S. C., & Sherman, S. J. (2000). The natural history of cigarette smoking from adolescence to adulthood in a midwestern community sample: Multiple trajectories and their psychosocial correlates. *Health Psychology*, *19*(3), 223–231. https://doi.org/10.1037/0278-6133.19.3.223

Choi, K., Fabian, L., Mottey, N., Corbett, A., & Forster, J. (2012). Young adults' favorable perceptions of snus, dissolvable tobacco products, and electronic cigarettes: Findings from a focus group study. *American Journal of Public Health*, *102*(11), 2088–2093. https://doi.org/10.2105/AJPH.2011.300525

Choi, W. S., Okuyemi, K. S., Kaur, H., & Ahluwalia, J. S. (2004). Comparison of smoking relapse curves among African-American smokers. *Addictive Behaviors*, *29*(8), 1679–1683. https://doi.org/10.1016/j.addbeh.2004.02.060

Clarke, T. C., Black, L. I., Stussman, B. J., Barnes, P. M., & Nahin, R. L. (2015). Trends in the use of complementary health approaches among adults: United States, 2002–2012. *National Health Statistics Reports*, (79), 1.

Cobb, C. O., Villanti, A. C., Graham, A. L., Pearson, J. L., Glasser, A. M., Rath, J. M., … Niaura, R. (2015). Markov modeling to estimate the population impact of emerging tobacco products: A proof-of-concept study. *Tobacco Regulatory Science*, *1*(2), 129–141. https://doi.org/10.18001/TRS.1.2.3

Coggins, C. R., Murrelle, E. L., Carchman, R. A., & Heidbreder, C. (2009). Light and intermittent cigarette smokers: A review (1989-2009). *Psychopharmacology (Berl)*, *207*(3), 343–363. https://doi.org/10.1007/s00213-009-1675-4

Coleman, B. N., Johnson, S. E., Tessman, G. K., Tworek, C., Alexander, J., Dickinson, D. M., … Green, K. M. (2016). "It's not smoke. It's not tar. It's not 4000 chemicals. Case closed": Exploring attitudes, beliefs, and perceived social norms of e-cigarette use among adult users. *Drug and Alcohol Dependence*, *159*, 80–85. https://doi.org/10.1016/j.drugalcdep.2015.11.028

Cooke, M. E., Nasim, A., Cho, S. B., Kendler, K. S., Clark, S. L., & Dick, D. M. (2016). Predicting tobacco use across the first year of college. *American Journal of Health Behavior*, *40*(4), 484–495. https://doi.org/10.5993/AJHB.40.4.10

Cooper, M., Loukas, A., Case, K. R., Marti, C. N., & Perry, C. L. (2018). A longitudinal study of risk perceptions and e-cigarette initiation among college students: Interactions with smoking status. *Drug and Alcohol Dependence*, *186*, 257–263. https://doi.org/10.1016/j.drugalcdep.2017.11.027

Costello, D. M., Dierker, L. C., Jones, B. L., & Rose, J. S. (2008). Trajectories of smoking from adolescence to early adulthood and their psychosocial risk factors. *Health Psychology*, *27*(6), 811–818. https://doi.org/10.1037/0278-6133.27.6.811

Cox, D. R., & Miller, H. D. (1996). *The theory of stochastic processes*. London: Chapman & Hall.

Crane, N. A., Langenecker, S. A., & Mermelstein, R. J. (2015). Gender differences in the associations among marijuana use, cigarette use, and symptoms of depression during adolescence and young adulthood. *Addictive Behaviors*, *49*, 33–39. https://doi.org/10.1016/j.addbeh.2015.05.014

Creamer, M. R., Loukas, A., Li, X., Pasch, K. E., Case, K., Crook, B., & Perry, C. L. (2016). College students' perceptions and knowledge of hookah use. *Drug and Alcohol Dependence*, *168*, 191–195. https://doi.org/10.1016/j.drugalcdep.2016.09.004

Creamer, M. R., Perry, C. L., Harrell, M. B., & Diamond, P. M. (2015). Trends in multiple tobacco product use among high school students. *Tobacco Regulatory Science*, *1*(3), 204–214. https://doi.org/10.18001/TRS.1.3.2

Critchley, J. A. (2003). Health effects associated with smokeless tobacco: A systematic review. *Thorax*, *58*(5), 435–443. https://doi.org/10.1136/thorax.58.5.435

Cunningham, J. A., & Selby, P. L. (2007). Implications of the normative fallacy in young adult smokers aged 19–24 years. *American Journal of Public Health*, *97*(8), 1399–1400. https://doi.org/10.2105/AJPH.2006.101071

Curry, S. J., Sporer, A. K., Pugach, O., Campbell, R. T., & Emery, S. (2007). Use of tobacco cessation treatments among young adult smokers: 2005 National Health Interview Survey. *American Journal of Public Health*, *97*(8), 1464–1469. https://doi.org/10.2105/AJPH.2006.103788

Darlow, S., & Lobel, M. (2012). Smoking behavior and motivational flexibility in light and heavy smokers. *Addictive Behaviors*, *37*(5), 668–673. https://doi.org/10.1016/j.addbeh.2012.02.001

Delnevo, C. D., Villanti, A. C., Wackowski, O. A., Gundersen, D. A., & Giovenco, D. P. (2016). The influence of menthol, e-cigarettes and other tobacco products on young adults' self-reported changes in past year smoking. *Tobacco Control*, *25*(5), 571–574. https://doi.org/10.1136/tobaccocontrol-2015-052325

Delnevo, C. D., Wackowski, O. A., Giovenco, D. P., Manderski, M. T. B., Hrywna, M., & Ling, P. M. (2014). Examining market trends in the United States smokeless tobacco use: 2005–2011. *Tobacco Control*, *23*(2), 107–112. https://doi.org/10.1136/tobaccocontrol-2012-050739

Dierker, L., Swendsen, J., Rose, J., He, J., Merikangas, K., & The Tobacco Etiology Research Network (TERN). (2012). Transitions to regular smoking and nicotine dependence in the Adolescent National Comorbidity Survey (NCS-A). *Annals of Behavioral Medicine*, *43*(3), 394–401. https://doi.org/10.1007/s12160-011-9330-9

DiFranza, J. R., Savageau, J. A., Fletcher, K., O'Loughlin, J., Pbert, L., Ockene, J. K., … Wellman, R. J. (2007). symptoms of tobacco dependence after brief intermittent use: The development and assessment of nicotine dependence in youth–2 study. *Archives of Pediatrics & Adolescent Medicine*, *161*(7), 704. https://doi.org/10.1001/archpedi.161.7.704

Do, E. K., Prom-Wormley, E. C., Fuemmeler, B. F., Dick, D. M., Kendler, K. S., & Maes, H. H. (2018). Associations between initial subjective experiences with tobacco and self-reported recent use in young adulthood. *Substance Use & Misuse*, 1–8. https://doi.org/10.1080/10826084.2018.1473435

Doran, N., & Brikmanis, K. (2016). Expectancies for and use of e-cigarettes and hookah among young adult non-daily smokers. *Addictive Behaviors*, *60*, 154–159. https://doi.org/10.1016/j.addbeh.2016.04.008

Doran, N., Godfrey, K. M., & Myers, M. G. (2015). Hookah use predicts cigarette smoking progression among college smokers. *Nicotine and Tobacco Research*, *17*(11), 1347–1353. https://doi.org/10.1093/ntr/ntu343

Dunbar, M. S., Shadel, W. G., Tucker, J. S., & Edelen, M. O. (2016). Use of and reasons for using multiple other tobacco products in daily and nondaily smokers:

Associations with cigarette consumption and nicotine dependence. *Drug and Alcohol Dependence*, *168*, 156–163. https://doi.org/10.1016/j.drugalcdep.2016.09.005

Dutra, L. M., Glantz, S. A., Lisha, N. E., & Song, A. V. (2017). Beyond experimentation: Five trajectories of cigarette smoking in a longitudinal sample of youth. *PLOS ONE*, *12*(2), e0171808. https://doi.org/10.1371/journal.pone.0171808

Enofe, N., Berg, C. J., & Nehl, E. J. (2014). alternative tobacco use among college students: Who is at highest risk? *American Journal of Health Behavior*, *38*(2), 180–189. https://doi.org/10.5993/AJHB.38.2.3

Etter, J. F. (2004). The psychological determinants of low-rate daily smoking. *Addiction*, *99*(10), 1342–1350. https://doi.org/10.1111/j.1360-0443.2004.00839.x

Etter, J. F. (2010). Electronic cigarettes: A survey of users. *BMC Public Health*, *10*(1). https://doi.org/10.1186/1471-2458-10-231

Everett, S. A., Husten, C. G., Kann, L., Warren, C. W., Sharp, D., & Crossett, L. (1999). Smoking initiation and smoking patterns among US college students. *Journal of American College Health*, *48*(2), 55–60. https://doi.org/10.1080/07448489909595674

Fagan, P., Brook, J. S., Rubenstone, E., Zhang, C., & Brook, D. W. (2009). Longitudinal precursors of young adult light smoking among African Americans and Puerto Ricans. *Nicotine and Tobacco Research*, *11*(2), 139–147. https://doi.org/10.1093/ntr/ntp009

Fagan, P., & Rigotti, N. A. (2009). Light and intermittent smoking: The road less traveled. *Nicotine and Tobacco Research*, *11*(2), 107–110. https://doi.org/10.1093/ntr/ntn015

Fish, L. J., Pollak, K. I., Scheuermann, T. S., Cox, L. S., Mathur, C., & Ahluwalia, J. S. (2015). Comparison of native light daily smokers and light daily smokers who were former heavy smokers. *Nicotine and Tobacco Research*, *17*(5), 546–551. https://doi.org/10.1093/ntr/ntu169

Fix, B. V., O'Connor, R. J., Vogl, L., Smith, D., Bansal-Travers, M., Conway, K. P., … Hyland, A. (2014). Patterns and correlates of polytobacco use in the United States over a decade: NSDUH 2002–2011. *Addictive Behaviors*, *39*(4), 768–781. https://doi.org/10.1016/j.addbeh.2013.12.015

Forman-Hoffman, V. L., Hedden, S. L., Miller, G. K., Brown, K., Teich, J., & Gfroerer, J. (2017). Trends in cigarette use, by serious psychological distress status in the United States, 1998–2013. *Addictive Behaviors*, *64*, 223–228. https://doi.org/10.1016/j.addbeh.2016.09.003

Fromme, K., Corbin, W. R., & Kruse, M. I. (2008). Behavioral risks during the transition from high school to college. *Developmental Psychology*, *44*(5), 1497–1504. https://doi.org/10.1037/a0012614

Garrett, B. E., Dube, S. R., Trosclair, A., Caraballo, R. S., Pechacek, T. F., & Centers for Disease Control and Prevention (CDC). (2011). Cigarette smoking—United States, 1965–2008. *MMWR Surveill Summ*, *60*(1), 109–113.

Gathuru, I. M., Tarter, R. E., & Klein-Fedyshin, M. (2015). Review of hookah tobacco smoking among college students: Policy implications and research recommendations. *The American Journal of Drug and Alcohol Abuse*, *41*(4), 272–280. https://doi.org/10.3109/00952990.2015.1043738

Gilman, S. E., Martin, L. T., Abrams, D. B., Kawachi, I., Kubzansky, L., Loucks, E. B., … Buka, S. L. (2008). Educational attainment and cigarette smoking: a causal association? *International Journal of Epidemiology*, *37*(3), 615–624. https://doi.org/10.1093/ije/dym250

Gilpin, E. A. (2005). How effective are tobacco industry bar and club marketing efforts in reaching young adults? *Tobacco Control*, *14*(3), 186–192. https://doi.org/10.1136/tc.2004.009712

Gilreath, T. D., Leventhal, A., Barrington-Trimis, J. L., Unger, J. B., Cruz, T. B., Berhane, K., … McConnell, R. (2016). Patterns of alternative tobacco product use: Emergence of hookah and e-cigarettes as preferred products amongst youth. *Journal of Adolescent Health*, *58*(2), 181–185. https://doi.org/10.1016/j.jadohealth.2015.10.001

Green, M. P., McCausland, K. L., Xiao, H., Duke, J. C., Vallone, D. M., & Healton, C. G. (2007). A closer look at smoking among young adults: Where tobacco control should focus its attention. *American Journal of Public Health*, *97*(8), 1427–1433. https://doi.org/10.2105/AJPH.2006.103945

Grekin, E. R., & Ayna, D. (2012). waterpipe smoking among college students in the united states: A review of the literature. *Journal of American College Health*, *60*(3), 244–249. https://doi.org/10.1080/07448481.2011.589419

Guillory, J., Johns, M., Farley, S. M., & Ling, P. M. (2015). Loose cigarette purchasing and nondaily smoking among young adult bar patrons in New York City. *American Journal of Public Health*, *105*(8), e140–e147. https://doi.org/10.2105/AJPH.2014.302518

Hair, E. C., Romberg, A. R., Niaura, R., Abrams, D. B., Bennett, M. A., Xiao, H., … Vallone, D. (2018). Longitudinal tobacco use transitions among adolescents and young adults: 2014–2016. *Nicotine and Tobacco Research*. https://doi.org/10.1093/ntr/ntx285

Hair, E., Rath, J., Pitzer, L., Emelle, B., Ganz, O., Halenar, M., … Vallone, D. (2017). Trajectories of hookah use: Harm perceptions from youth to young adulthood. *American Journal of Health Behavior*, *41*(3), 240–247. https://doi.org/10.5993/AJHB.41.3.3

Hammond, D. (2005). Smoking behaviour among young adults: Beyond youth prevention. *Tobacco Control*, *14*(3), 181–185. https://doi.org/10.1136/tc.2004.009621

Heinz, A. J., Giedgowd, G. E., Crane, N. A., Veilleux, J. C., Conrad, M., Braun, A. R., … Kassel, J. D. (2013). A comprehensive examination of hookah smoking in college students: Use patterns and contexts, social norms and attitudes, harm perception,

psychological correlates and co-occurring substance use. *Addictive Behaviors*, *38*(11), 2751–2760. https://doi.org/10.1016/j.addbeh.2013.07.009

Hu, S. S. (2016). Tobacco product use among adults—United States, 2013–2014. *MMWR. Morbidity and Mortality Weekly Report*, *65*.

Huh, J., Huang, Z., Liao, Y., Pentz, M., & Chou, C.-P. (2013). Transitional life events and trajectories of cigarette and alcohol use during emerging adulthood: Latent class analysis and growth mixture modeling. *Journal of Studies on Alcohol and Drugs*, *74*(5), 727–735. https://doi.org/10.15288/jsad.2013.74.727

Hukkinen, M., Kaprio, J., Broms, U., Koskenvuo, M., & Korhonen, T. (2009). Characteristics and consistency of light smoking: Long-term follow-up among Finnish adults. *Nicotine and Tobacco Research*, *11*(7), 797–805. https://doi.org/10.1093/ntr/ntp065

Husten, C. G. (2009). How should we define light or intermittent smoking? Does it matter? *Nicotine and Tobacco Research*, *11*(2), 111–121. https://doi.org/10.1093/ntr/ntp010

Hyland, A., Rezaishiraz, H., Bauer, J., Giovino, G. A., & Cummings, K. M. (2005). Characteristics of low-level smokers. *Nicotine and Tobacco Research*, *7*(3), 461–468. https://doi.org/10.1080/14622200500125369

Jackson, C. (2011). Multi-State Models for Panel Data: The msm Package for R. *Journal of Statistical Software*, *38*(8). https://doi.org/10.18637/jss.v038.i08

Jackson, C. (2018). Package 'msm.'

Jackson, K. M., Sher, K. J., Rose, R. J., & Kaprio, J. (2009). Trajectories of tobacco use from adolescence to adulthood: Are the most informative phenotypes tobacco specific. *Monographs of the National Cancer Institute*, *22*.

Jackson, K. M., Sher, K. J., & Schulenberg, J. E. (2005). Conjoint developmental trajectories of young adult alcohol and tobacco use. *Journal of Abnormal Psychology*, *114*(4), 612–626. https://doi.org/10.1037/0021-843X.114.4.612

Jamal, A., Brian, K. A., Neff, L. J., Whitmill, J., Babb, S. D., & Graffunder, C. M. (2016). Current cigarette smoking among adults—United States, 2005–2015. *MMWR. Morbidity and Mortality Weekly Report*, *65*(44), 1205–1211.

Jamal, A., Homa, D. M., O'Connor, E., Babb, S. D., Caraballo, R. S., Singh, T., … King, B. A. (2015). Current cigarette smoking among adults—United States, 2005–2014. *MMWR Morb Mortal Wkly Rep*, *64*(44), 1233–1240.

Jamal, A., Phillips, E., Gentzke, A. S., Homa, D. M., Babb, S. D., King, B. A., & Neff, L. J. (2018). Current cigarette smoking among adults — United States, 2016. *MMWR. Morbidity and Mortality Weekly Report*, *67*(2), 53–59. https://doi.org/10.15585/mmwr.mm6702a1

Jorenby, D. E., Smith, S. S., Fiore, M. C., & Baker, T. B. (2016). Nicotine levels, withdrawal symptoms, and smoking reduction success in real world use: A comparison of cigarette smokers and dual users of both cigarettes and e-cigarettes. *Drug and Alcohol Dependence*. https://doi.org/10.1016/j.drugalcdep.2016.10.041

Kalkhoran, S., & Glantz, S. A. (2016). E-cigarettes and smoking cessation in real-world and clinical settings: A systematic review and meta-analysis. *The Lancet Respiratory Medicine*, *4*(2), 116–128. https://doi.org/10.1016/S2213-2600(15)00521-4

Kaplan, D. (2008). An overview of Markov chain methods for the study of stage-sequential developmental processes. *Developmental Psychology*, *44*(2), 457–467. https://doi.org/10.1037/0012-1649.44.2.457

Kasza, K. A., Ambrose, B. K., Conway, K. P., Borek, N., Taylor, K., Goniewicz, M. L., … Hyland, A. J. (2017). Tobacco-product use by adults and youths in the United States in 2013 and 2014. *New England Journal of Medicine*, *376*(4), 342–353. https://doi.org/10.1056/NEJMsa1607538

Kaufman, A. R., Land, S., Parascandola, M., Augustson, E., & Backinger, C. L. (2015). Tobacco use transitions in the United States: The National Longitudinal Study of Adolescent Health. *Preventive Medicine*, *81*, 251–257. https://doi.org/10.1016/j.ypmed.2015.08.026

Kenford, S. L., Wetter, D. W., Welsch, S. K., Smith, S. S., Fiore, M. C., & Baker, T. B. (2005). Progression of college-age cigarette samplers: What influences outcome. *Addictive Behavior*, *30*(2), 285–294. https://doi.org/10.1016/j.addbeh.2004.05.017

Kim, A. E., Arnold, K. Y., & Makarenko, O. (2014). E-cigarette advertising expenditures in the U.S., 2011-2012. *American Journal of Preventive Medicine*, *46*(4), 409–412. https://doi.org/10.1016/j.amepre.2013.11.003

Kim, H.-J., Fay, M. P., Feuer, E. J., & Midthune, D. N. (2000). Permutation tests for joinpoint regression with applications to cancer rates. *Statistics in Medicine*, *19*(3), 335–351. https://doi.org/10.1002/(SICI)1097-0258(20000215)19:3<335::AID-SIM336>3.0.CO;2-Z

King, A. C., & Epstein, A. M. (2005). Alcohol Dose-Dependent Increases in Smoking Urge in Light Smokers: *Alcoholism: Clinical & Experimental Research*, *29*(4), 547–552. https://doi.org/10.1097/01.ALC.0000158839.65251.FE

King, B. A., Alam, S., Promoff, G., Arrazola, R., & Dube, S. R. (2013). Awareness and ever-use of electronic cigarettes among U.S. Adults, 2010-2011. *Nicotine and Tobacco Research*, *15*(9), 1623–1627. https://doi.org/10.1093/ntr/ntt013

King, B. A., Dube, S. R., & Tynan, M. A. (2012). Current tobacco use among adults in the United States: Findings from the National Adult Tobacco Survey. *American Journal of Public Health*, *102*(11), e93–e100. https://doi.org/10.2105/AJPH.2012.301002

Klein, E. G., Bernat, D. H., Lenk, K. M., & Forster, J. L. (2013). Nondaily smoking patterns in young adulthood. *Addictive Behaviors*, *38*(7), 2267–2272. https://doi.org/10.1016/j.addbeh.2013.03.005

Klein, E. G., Forster, J. L., & Erickson, D. J. (2013). longitudinal predictors of stopping smoking in young adulthood. *Journal of Adolescent Health*, *53*(3), 363–367. https://doi.org/10.1016/j.jadohealth.2013.04.012

Kotz, D., Fidler, J., & West, R. (2012). Very low rate and light smokers: smoking patterns and cessation-related behaviour in England, 2006-11: Very low rate and light smokers. *Addiction*, *107*(5), 995–1002. https://doi.org/10.1111/j.1360-0443.2011.03739.x

Langeheine, R., & van de Pol, F. (2002). Latent Markov Chains. In J. A. Hagenaars & A. L. McCutcheon (Eds.), *Applied Latent Class Analysis* (pp. 304–342). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511499531.012

Latimer, L. A., Batanova, M., & Loukas, A. (2014). Prevalence and harm perceptions of various tobacco products among college students. *Nicotine and Tobacco Research*, *16*(5), 519–526. https://doi.org/10.1093/ntr/ntt174

Lawrence, D., Mitrou, F., & Zubrick, S. R. (2009). Smoking and mental illness: Results from population surveys in Australia and the United States. *BMC Public Health*, *9*, 285. https://doi.org/10.1186/1471-2458-9-285

Lee, D. C., Peters, J. R., Adams, Z. W., Milich, R., & Lynam, D. R. (2015). Specific dimensions of impulsivity are differentially associated with daily and non-daily cigarette smoking in young adults. *Addictive Behaviors*, *46*, 82–85. https://doi.org/10.1016/j.addbeh.2015.03.009

Lee, Y. O., Bahreinifar, S., & Ling, P. M. (2014). Understanding tobacco-related attitudes among college and noncollege young adult hookah and cigarette users. *Journal of American College Health*, *62*(1), 10–18. https://doi.org/10.1080/07448481.2013.842171

Lee, Y. O., Hebert, C. J., Nonnemaker, J. M., & Kim, A. E. (2014). Multiple tobacco product use among adults in the United States: Cigarettes, cigars, electronic cigarettes, hookah, smokeless tobacco, and snus. *Preventive Medicine*, *62*, 14–19. https://doi.org/10.1016/j.ypmed.2014.01.014

Lee, Y. O., & Kim, A. E. (2014). "Vape shops" and "E-Cigarette lounges" open across the USA to promote ENDS. *Tobacco Control*. https://doi.org/10.1136/tobaccocontrol-2013-051437

Lenk, K. M., Erickson, D. J., & Forster, J. L. (2017). Trajectories of cigarette smoking from teens to young adulthood: 2000 to 2013. *American Journal of Health Promotion*, 089011711769635. https://doi.org/10.1177/0890117117696358

Lenz, B. K. (2003). Correlates of Young Adult Tobacco Use: Application of a transition framework. *The Journal of School Nursing*, *19*(4), 232–237. https://doi.org/10.1177/10598405030190040901

Lenk, K. M., Chen, V., Bernat, D. H., Forster, J. L., & Rode, P. A. (2009). Characterizing and Comparing Young Adult Intermittent and Daily Smokers. *Substance Use & Misuse*, *44*(14), 2128–2140. https://doi.org/10.3109/10826080902864571

Leung, J., Gartner, C., Hall, W., Lucke, J., & Dobson, A. (2012). A longitudinal study of the bi-directional relationship between tobacco smoking and psychological distress in a community sample of young Australian women. *Psychological Medicine*, *42*(06), 1273–1282. https://doi.org/10.1017/S0033291711002261

Levinson, A. H., Campo, S., Gascoigne, J., Jolly, O., Zakharyan, A., & Tran, Z. V. (2007). Smoking, but not smokers: Identity among college students who smoke cigarettes. *Nicotine and Tobacco Research*, *9*(8), 845–852. https://doi.org/10.1080/14622200701484987

Levy, D. E., Biener, L., & Rigotti, N. A. (2009). The natural history of light smokers: A population-based cohort study. *Nicotine and Tobacco Research*, *11*(2), 156–163. https://doi.org/10.1093/ntr/ntp011

Li, X., Loukas, A., & Perry, C. L. (2018). Very light smoking and alternative tobacco use among college students. *Addictive Behaviors*, *81*, 22–25. https://doi.org/10.1016/j.addbeh.2018.01.038

Lindström, M., Isacsson, S.-O., & Malmö Shoulder-Neck Study Group. (2002). Long term and transitional intermittent smokers: a longitudinal study. *Tobacco Control*, *11*(1), 61–67.

Ling, P. M., & Glantz, S. A. (2002). Why and how the tobacco industry sells cigarettes to young adults: Evidence from industry documents. *American Journal of Public Health*, *92*(6), 908–916. https://doi.org/10.2105/AJPH.92.6.908

Ling, P. M., & Glantz, S. A. (2004). Tobacco industry research on smoking cessation. Recapturing young adults and other recent quitters. *Journal of General Internal Medicine*, *19*(5 Pt 1), 419–426. https://doi.org/10.1111/j.1525-1497.2004.30358.x

Ling, P. M., Neilands, T. B., & Glantz, S. A. (2009). Young adult smoking behavior: A national survey. *American Journal of Preventive Medicine*, *36*(5), 389-394 e2. https://doi.org/10.1016/j.amepre.2009.01.028

Loukas, A., Batanova, M., Fernandez, A., & Agarwal, D. (2015). Changes in use of cigarettes and non-cigarette alternative products among college students. *Addictive Behaviors*, *49*, 46–51. https://doi.org/10.1016/j.addbeh.2015.05.005

Loukas, A., Chow, S., Pasch, K. E., Li, X., Hinds III, J. T., Marti, C. N., … Perry, C. L. (2016). College students' polytobacco use, cigarette cessation, and dependence. *American Journal of Health Behavior*, *40*(4), 514–522. https://doi.org/10.5993/AJHB.40.4.13

Marynak, K. L., Gammon, D. G., King, B. A., Loomis, B. R., Fulmer, E. B., Wang, T. W., & Rogers, T. (2017). National and state trends in sales of cigarettes and e-cigarettes, U.S., 2011–2015. *American Journal of Preventive Medicine*. https://doi.org/10.1016/j.amepre.2017.01.016

Mathur, C., Stigler, M. H., Erickson, D. J., Perry, C. L., & Forster, J. L. (2014). Transitions in smoking behavior during emerging adulthood: A longitudinal analysis of the effect of home smoking bans. *American Journal of Public Health*, *104*(4), 715–720. https://doi.org/10.2105/AJPH.2013.301642

Maziak, W., Taleb, Z. B., Bahelah, R., Islam, F., Jaber, R., Auf, R., & Salloum, R. G. (2015). The global epidemiology of waterpipe smoking. *Tobacco Control*, *24*(Suppl 1), i3–i12. https://doi.org/10.1136/tobaccocontrol-2014-051903

McDermott, L., Dobson, A., & Owen, N. (2007). Occasional tobacco use among young adult women: a longitudinal analysis of smoking transitions. *Tobacco Control*, *16*(4), 248–254. https://doi.org/10.1136/tc.2006.018416

McIntire, R. K., Macy, J. T., Seo, D.-C., Nelson, A. A., & Kolbe, L. J. (2014). Secondhand smoke exposure in cars and rooms: Trend comparisons among subpopulations of nonsmoking U.S. middle and high school students. *Nicotine and Tobacco Research*, *16*(6), 663–671. https://doi.org/10.1093/ntr/ntt207

McMillen, R. C., Gottlieb, M. A., Shaefer, R. M. W., Winickoff, J. P., & Klein, J. D. (2015). Trends in electronic cigarette use among U.S. adults: Use is increasing in both smokers and nonsmokers. *Nicotine and Tobacco Research*, *17*(10), 1195–1202. https://doi.org/10.1093/ntr/ntu213

McMillen, R., Maduka, J., & Winickoff, J. (2012). Use of emerging tobacco products in the United States. *Journal of Environmental and Public Health*, *2012*, 1–8. https://doi.org/10.1155/2012/989474

Meier, E., Lechner, W. V., Miller, M. B., & Wiener, J. L. (2013). Changes in smokeless tobacco use over four years following a campus-wide anti-tobacco intervention. *Nicotine and Tobacco Research*, *15*(8), 1382–1387. https://doi.org/10.1093/ntr/nts337

Meier, E. M., Tackett, A. P., Miller, M. B., Grant, D. M., & Wagener, T. L. (2015). Which nicotine products are gateways to regular use? *American Journal of*

Preventive Medicine, *48*(1), S86–S93. https://doi.org/10.1016/j.amepre.2014.09.018

Mejia, A. B., & Ling, P. M. (2010). Tobacco industry consumer research on smokeless tobacco users and product development. *American Journal of Public Health*, *100*(1), 78–87. https://doi.org/10.2105/AJPH.2008.152603

Mhoon, K. B., Chan, W., Del Junco, D. J., & Vernon, S. W. (2010). A continuous-time Markov chain approach analyzing the stages of change construct from a health promotion intervention. *JP Journal of Biostatistics*, *4*(3), 213–226.

Moran, S., Wechsler, H., & Rigotti, N. A. (2004). Social smoking among US college students. *Pediatrics*, *114*(4), 1028–1034. https://doi.org/10.1542/peds.2003-0558-L

Muthen, B., & Muthen, L. K. (2000). Integrating person-centered and variable-centered analyses: growth mixture modeling with latent trajectory classes. *Alcoholism: Clinical and Experimental Research*, *24*(6), 882–891. https://doi.org/10.1111/j.1530-0277.2000.tb02070.x

Nasim, A., Khader, Y., Blank, M. D., Cobb, C. O., & Eissenberg, T. (2012). Trends in alternative tobacco use among light, moderate, and heavy smokers in adolescence, 1999–2009. *Addictive Behaviors*, *37*(7), 866–870. https://doi.org/10.1016/j.addbeh.2012.03.001

National Association of Attorneys General. (1998). Master Settlement Agreement.

Nelson, D. E., Mowery, P., Asman, K., Pederson, L. L., O'Malley, P. M., Malarcher, A., … Pechacek, T. F. (2008). Long-term trends in adolescent and young adult smoking in the United States: Metapatterns and implications. *American Journal of Public Health*, *98*(5), 905–915. https://doi.org/10.2105/AJPH.2007.115931

Nelson, S. E., Van Ryzin, M. J., & Dishion, T. J. (2015). Alcohol, marijuana, and tobacco use trajectories from age 12 to 24 years: Demographic correlates and young adult substance use problems. *Development and Psychopathology*, *27*(01), 253–277. https://doi.org/10.1017/S0954579414000650

Nguyen, Q. B., & Zhu, S.-H. (2009). Intermittent smokers who used to smoke daily: A preliminary study on smoking situations. *Nicotine and Tobacco Research*, *11*(2), 164–170. https://doi.org/10.1093/ntr/ntp012

Noland, M., Ickes, M. J., Rayens, M. K., Butler, K., Wiggins, A. T., & Hahn, E. J. (2016). Social influences on use of cigarettes, e-cigarettes, and hookah by college students. *Journal of American College Health*, *64*(4), 319–328. https://doi.org/10.1080/07448481.2016.1138478

Nollen, N. L., Ahluwalia, J. S., Lei, Y., Yu, Q., Scheuermann, T. S., & Mayo, M. S. (2016). Adult cigarette smokers at highest risk for concurrent alternative tobacco product use among a racially/ethnically and socioeconomically diverse sample. *Nicotine and Tobacco Research*, *18*(4), 386–394. https://doi.org/10.1093/ntr/ntv110

Okuyemi, K. S., Harris, K. J., Scheibmeir, M., Choi, W. S., Powell, J., & Ahluwalia, J. S. (2002). Light smokers: Issues and recommendations. *Nicotine and Tobacco Research*, *4 Suppl 2*, S103-12. https://doi.org/10.1080/1462220021000032726

Orlando, M., Tucker, J. S., Ellickson, P. L., & Klein, D. J. (2004). Developmental trajectories of cigarette smoking and their correlates from early adolescence to young adulthood. *Journal of Consulting and Clinical Psychology*, *72*(3), 400–410. https://doi.org/10.1037/0022-006X.72.3.400

Paavola, M., Vartiainen, E., & Haukkala, A. (2004). Smoking, alcohol use, and physical activity: A 13-year longitudinal study ranging from adolescence into adulthood. *Journal of Adolescent Health*, *35*(3), 238–244. https://doi.org/10.1016/j.jadohealth.2003.12.004

Parascandola, M., Augustson, E., & Rose, A. (2009). Characteristics of current and recent former smokers associated with the use of new potential reduced-exposure tobacco products. *Nicotine and Tobacco Research*, *11*(12), 1431–1438. https://doi.org/10.1093/ntr/ntp157

Perry, C. L., Pérez, A., Bluestein, M., Garza, N., Obinwa, U., Jackson, C., ... & Harrell, M. B. (2018). Youth or young adults: Which group is at highest risk for tobacco use onset? *Journal of Adolescent Health*. https://doi.org/10.1016/j.jadohealth.2018.04.011

Phillips, E., Wang, T. W., Husten, C. G., Corey, C. G., Apelberg, B. J., Jamal, A., … King, B. A. (2017). Tobacco product use among adults — United States, 2015.

MMWR. Morbidity and Mortality Weekly Report, *66*(44), 1209–1215. https://doi.org/10.15585/mmwr.mm6644a2

Pierce, J. P., Messer, K., White, M. M., Cowling, D. W., & Thomas, D. P. (2011). Prevalence of heavy smoking in California and the United States, 1965-2007. *JAMA*, *305*(11), 1106. https://doi.org/10.1001/jama.2011.334

Pierce, J. P., White, M. M., & Messer, K. (2009). Changing age-specific patterns of cigarette consumption in the United States, 1992-2002: Association with smoke-free homes and state-level tobacco control activity. *Nicotine and Tobacco Research*, *11*(2), 171–177. https://doi.org/10.1093/ntr/ntp014

Pinsker, E. A., Berg, C. J., Nehl, E. J., Prokhorov, A. V., Buchanan, T. S., & Ahluwalia, J. S. (2013). Intent to quit among daily and non-daily college student smokers. *Health Education Research*, *28*(2), 313–325. https://doi.org/10.1093/her/cys116

Popova, L., & Ling, P. M. (2013). Alternative tobacco product use and smoking cessation: A national study. *American Journal of Public Health*, *103*(5), 923–930. https://doi.org/10.2105/AJPH.2012.301070

Pratt, L. A., & Brody, D. J. (2010). Depression and smoking in the U.S. household population aged 20 and over, 2005-2008. *NCHS Data Brief*, (34), 1–8.

Primack, B. A., Soneji, S., Stoolmiller, M., Fine, M. J., & Sargent, J. D. (2015). Progression to traditional cigarette smoking after electronic cigarette use among US adolescents and young adults. *JAMA Pediatrics*, *169*(11), 1018. https://doi.org/10.1001/jamapediatrics.2015.1742

Presson, C. C., Chassin, L., & Sherman, S. J. (2002). Psychosocial antecedents of tobacco chipping. *Health Psychology*, *21*(4), 384–392.

Primack, B. A., Shensa, A., Kim, K. H., Carroll, M. V., Hoban, M. T., Leino, E. V., … Fine, M. J. (2013). waterpipe smoking among u.s. university students. *Nicotine and Tobacco Research*, *15*(1), 29–35. https://doi.org/10.1093/ntr/nts076

Ramo, D. E., Liu, H., & Prochaska, J. J. (2012). Tobacco and marijuana use among adolescents and young adults: A systematic review of their co-use. *Clinical Psychology Review*, *32*(2), 105–121. https://doi.org/10.1016/j.cpr.2011.12.002

Rath, J. M., Villanti, A. C., Abrams, D. B., & Vallone, D. M. (2012). Patterns of tobacco use and dual use in US young adults: The missing link between youth prevention and adult cessation. *Journal of Environmental and Public Health*, *2012*, 1–9. https://doi.org/10.1155/2012/679134

Regan, A. K., Dube, S. R., & Arrazola, R. (2012). Smokeless and flavored tobacco products in the U.S. *American Journal of Preventive Medicine*, *42*(1), 29–36. https://doi.org/10.1016/j.amepre.2011.08.019

Reyes-Guzman, C. M., Pfeiffer, R. M., Lubin, J., Freedman, N. D., Cleary, S. D., Levine, P. H., & Caporaso, N. E. (2017). Determinants of light and intermittent smoking in the United States: Results from three pooled national health surveys. *Cancer Epidemiology Biomarkers & Prevention*, *26*(2), 228–239. https://doi.org/10.1158/1055-9965.EPI-16-0028

Richardson, A., Pearson, J., Xiao, H., Stalgaitis, C., & Vallone, D. (2014). Prevalence, harm perceptions, and reasons for using noncombustible tobacco products among current and former smokers. *American Journal of Public Health*, *104*(8), 1437–1444. https://doi.org/10.2105/AJPH.2013.301804

Richardson, A., Williams, V., Rath, J., Villanti, A. C., & Vallone, D. (2014). The next generation of users: Prevalence and longitudinal patterns of tobacco use among US Young adults. *American Journal of Public Health*, *104*(8), 1429–1436. https://doi.org/10.2105/AJPH.2013.301802

Ridner, S. L., Myers, J. A., Hahn, E. J., & Ciszewski, T. N. (2010). College students' exposure to tobacco marketing in nightclubs and bars. *Journal of American College Health*, *59*(3), 159–164. https://doi.org/10.1080/07448481.2010.483716

Robertson, L., Iosua, E., McGee, R., & Hancox, R. J. (2016). Nondaily, low-rate daily, and high-rate daily smoking in young adults: A 17-year follow-up. *Nicotine and Tobacco Research*, *18*(5), 943–949. https://doi.org/10.1093/ntr/ntv167

Ryan, H., Trosclair, A., & Gfroerer, J. (2012). Adult current smoking: differences in definitions and prevalence estimates—NHIS and NSDUH, 2008. *Journal of Environmental and Public Health*, *2012*, 1–11. https://doi.org/10.1155/2012/918368

SAS. (2009). SAS User's Guide: Statistics, Release 9.1.

SAS Institute Inc. (2015). AS/STAT® 14.1 User's Guide. Cary, NC: SAS Institute Inc. SAS Institute Inc.

Sayette, M. A., Martin, C. S., Wertz, J. M., Shiffman, S., & Perrott, M. A. (2001). A multi-dimensional analysis of cue-elicited craving in heavy smokers and tobacco chippers. *Addiction*, *96*(10), 1419–1432. https://doi.org/10.1080/09652140120075152

Schane, R. E., Ling, P. M., & Glantz, S. A. (2010). Health effects of light and intermittent smoking: a review. *Circulation*, *121*(13), 1518–1522. https://doi.org/10.1161/CIRCULATIONAHA.109.904235

Schane, Rebecca E., Glantz, S. A., & Ling, P. M. (2009). Nondaily and social smoking: An increasingly prevalent pattern. *Archives of Internal Medicine*, *169*(19). https://doi.org/10.1001/archinternmed.2009.315

Schauer, G. L., Berg, C. J., Kegler, M. C., Donovan, D. M., & Windle, M. (2015). Assessing the overlap between tobacco and marijuana: Trends in patterns of co-use of tobacco and marijuana in adults from 2003–2012. *Addictive Behaviors*, *49*, 26–32. https://doi.org/10.1016/j.addbeh.2015.05.012

Schauer, G. L., Malarcher, A. M., & Mowery, P. (2016). National trends in frequency and amount of nondaily smoking, and relation to quit attempts, 2000–2012. *Nicotine and Tobacco Research*, *18*(6), 1539–1544. https://doi.org/10.1093/ntr/ntv258

Scheuermann, T. S., Mburu, W. E., Mathur, C., & Ahluwalia, J. S. (2015). Correlates of converted and native nondaily smoking. *Nicotine and Tobacco Research*, *17*(9), 1112–1119. https://doi.org/10.1093/ntr/ntu272

Schoenborn, C. A., Adams, P. F., & Peregoy, J. A. (2013). Health behaviors of adults: United States, 2008-2010. *Vital and Health Statistics. Series 10, Data from the National Health Survey*, (257), 1–184.

Schoenborn, C. A., & Gindi, R. M. (2015). Electronic cigarette use among adults: United States, 2014 (pp. 1-8). Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics.

Shepardson, R. L., & Hustad, J. T. P. (2016). Hookah tobacco smoking during the transition to college: Prevalence of other substance use and predictors of initiation. *Nicotine and Tobacco Research*, *18*(5), 763–769. https://doi.org/10.1093/ntr/ntv170

Shiffman, S. (1989). Tobacco "chippers"--individual differences in tobacco dependence. *Psychopharmacology*, *97*(4), 539–547.

Shiffman, S., Dunbar, M. S., Kirchner, T. R., Li, X., Tindle, H. A., Anderson, S. J., … Ferguson, S. G. (2015). Cue reactivity in converted and native intermittent smokers. *Nicotine and Tobacco Research*, *17*(1), 119–123. https://doi.org/10.1093/ntr/ntu147

Shiffman, S., Dunbar, M. S., Li, X., Scholl, S. M., Tindle, H. A., Anderson, S. J., & Ferguson, S. G. (2014). Smoking patterns and stimulus control in intermittent and daily smokers. *PLoS ONE*, *9*(3), e89911. https://doi.org/10.1371/journal.pone.0089911

Shiffman, S., Tindle, H., Li, X., Scholl, S., Dunbar, M., & Mitchell-Miland, C. (2012). Characteristics and smoking patterns of intermittent smokers. *Experimental and Clinical Psychopharmacology*, *20*(4), 264–277. https://doi.org/10.1037/a0027546

Singh, T., Arrazola, R. A., Corey, C. G., Husten, C. G., Neff, L. J., Homa, D. M., & King, B. A. (2016). Tobacco use among middle and high school students — United States, 2011–2015. *MMWR. Morbidity and Mortality Weekly Report*, *65*(14), 361–367. https://doi.org/10.15585/mmwr.mm6514a1

Snyder, T., de Brey, C., & Dillow, S. (2016). *Digest of Education Statistics, 2014*. Retrieved from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2016006

Soneji, S., Barrington-Trimis, J. L., Wills, T. A., Leventhal, A. M., Unger, J. B., Gibson, L. A., … Sargent, J. D. (2017). Association between initial use of e-cigarettes and subsequent cigarette smoking among adolescents and young adults: A systematic review and meta-analysis. *JAMA Pediatrics*, *171*(8), 788. https://doi.org/10.1001/jamapediatrics.2017.1488

Soneji, S., Sargent, J. D., Tanski, S. E., & Primack, B. A. (2015). associations between initial water pipe tobacco smoking and snus use and subsequent cigarette smoking: Results from a longitudinal study of US adolescents and young adults. *JAMA Pediatrics*, *169*(2), 129. https://doi.org/10.1001/jamapediatrics.2014.2697

Soneji, S., Sargent, J., & Tanski, S. (2016). Multiple tobacco product use among US adolescents and young adults. *Tobacco Control*, *25*(2), 174–180. https://doi.org/10.1136/tobaccocontrol-2014-051638

Song, A. V., & Ling, P. M. (2011). Social smoking among young adults: Investigation of intentions and attempts to quit. *American Journal of Public Health*, *101*(7), 1291–1296. https://doi.org/10.2105/AJPH.2010.300012

Statistical Research and Applications Branch, N. C. I. (2017). Joinpoint Regression Program, Version 4.5. 0.1.

Sterling, K. L., Moore, R. S., Pitts, N., Duong, M., Ford, K. H., & Eriksen, M. P. (2013). Exposure to celebrity-endorsed small cigar promotions and susceptibility to use among young adult cigarette smokers. *Journal of Environmental and Public Health*, *2013*, 1–6. https://doi.org/10.1155/2013/520286

Substance Abuse and Mental Health Services Administration. (2012). The NSDUH report: Trends in cigarette use among adolescents and young adults. Rockvill, MD. Retrieved from http://archive.samhsa.gov/data/2k12/NSDUH047/SR047CigaretteTrends2012.htm

Substance Abuse and Mental Health Services Administration. (2014). Results from the 2013 National Survey on Drug Use and Health: Summary of national findings. Rockvill, MD. Retrieved from https://www.samhsa.gov/data/sites/default/files/NSDUHresultsPDFWHTML2013/Web/NSDUHresults2013.pdf

Substance Abuse and Mental Health Services Administration. (2017). National Survey on Drug Use and Health. Retrieved from https://nsduhweb.rti.org/respweb/homepage.cfm

Sung, H.-Y., Wang, Y., Yao, T., Lightwood, J., & Max, W. (2016). Polytobacco use of cigarettes, cigars, chewing tobacco, and snuff among US adults. *Nicotine and Tobacco Research*, *18*(5), 817–826. https://doi.org/10.1093/ntr/ntv147

Sutfin, E. L., McCoy, T. P., Berg, C. J., Champion, H., Helme, D. W., O'Brien, M. C., & Wolfson, M. (2012). Tobacco use by college students: a comparison of daily and nondaily smokers. *American Journal of Health Behavior*, *36*(2), 218–229. https://doi.org/10.5993/AJHB.36.2.7

Sutfin, E. L., McCoy, T. P., Morrell, H. E., Hoeppner, B. B., & Wolfson, M. (2013). Electronic cigarette use by college students. *Drug and Alcohol Dependence*, *131*(3), 214–221. https://doi.org/10.1016/j.drugalcdep.2013.05.001

Sutfin, E. L., Reboussin, B. A., Debinski, B., Wagoner, K. G., Spangler, J., & Wolfson, M. (2015). The impact of trying electronic cigarettes on cigarette smoking by college students: A prospective analysis. *American Journal of Public Health*, *105*(8), e83–e89. https://doi.org/10.2105/AJPH.2015.302707

Sutfin, E. L., Reboussin, B. A., McCoy, T. P., & Wolfson, M. (2009). Are college student smokers really a homogeneous group? A latent class analysis of college student smokers. *Nicotine and Tobacco Research*, *11*(4), 444–454. https://doi.org/10.1093/ntr/ntp006

Thompson, B., Coronado, G., Chen, L., Thompson, L. A., Halperin, A., Jaffe, R., … Zbikowski, S. (2007). Prevalence and characteristics of smokers at 30 Pacific

Northwest colleges and universities. *Nicotine and Tobacco Research*, *9*(3), 429–438. https://doi.org/10.1080/14622200701188844

Thrul, J., Ferguson, S. G., & Bühler, A. (2016). How do light and intermittent smokers differ from heavy smokers in young adulthood: The role of smoking restraint strategies. *Journal of Psychoactive Drugs*, 1–6. https://doi.org/10.1080/02791072.2016.1172744

Trinidad, D. R., Perez-Stable, E. J., Emery, S. L., White, M. M., Grana, R. A., & Messer, K. S. (2009). Intermittent and light daily smoking across racial/ethnic groups in the United States. *Nicotine and Tobacco Research*, *11*(2), 203–210. https://doi.org/10.1093/ntr/ntn018

Trinidad, D. R., Perez-Stable, E. J., White, M. M., Emery, S. L., & Messer, K. (2011). A nationwide analysis of US racial/ethnic disparities in smoking behaviors, smoking cessation, and cessation-related factors. *American Journal of Public Health*, *101*(4), 699–706. https://doi.org/10.2105/AJPH.2010.191668

Trumbo, C. W., & Kim, S. J. "Sage." (2015). The effect of electronic cigarette advertising on intended use among college students. *Addictive Behaviors*, *46*, 77–81. https://doi.org/10.1016/j.addbeh.2015.03.005

Tucker, J., Ellickson, P., & Klein, D. (2003). Predictors of the transition to regular smoking during adolescence and young adulthood. *Journal of Adolescent Health*, *32*(4), 314–324. https://doi.org/10.1016/S1054-139X(02)00709-7

US Department of Health and Human Services. (2012). Preventing tobacco use among youth and young adults: A report of the Surgeon General. *Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health*, *3*.

US Food and Drug Administration. (2016a). Cigars, Cigarillos, Little Filtered Cigars. Retrieved May 22, 2017, from https://www.fda.gov/TobaccoProducts/Labeling/ProductsIngredientsComponents/ucm482562.htm

US Food and Drug Administration. (2016b). Hookah Tobacco (Shisha or Waterpipe Tobacco). Retrieved May 22, 2017, from https://www.fda.gov/TobaccoProducts/Labeling/%20ProductsIngredientsComponents/ucm482575.htm

US Food and Drug Administration. (2016c). Smokeless Tobacco Products, Including Dip, Snuff, and Chewing Tobacco. Retrieved May 22, 2017, from https://www.fda.gov/TobaccoProducts/Labeling/ProductsIngredientsComponents/ucm482582.htm

US Food and Drug Administration. (2016d). Vaporizers, e-cigarettes, and other electronic nicotine delivery systems (ENDS). Retrieved May 22, 2017, from https://www.fda.gov/TobaccoProducts/Labeling/ProductsIngredientsComponents/ucm456610.htm

Villanti, A. C., Pearson, J. L., Cantrell, J., Vallone, D. M., & Rath, J. M. (2015). Patterns of combustible tobacco use in U.S. young adults and potential response to graphic cigarette health warning labels. *Addict Behav*, *42*, 119–125. https://doi.org/10.1016/j.addbeh.2014.11.011

Villanti, Andrea C., Johnson, A. L., Rath, J. M., Williams, V., Vallone, D. M., Abrams, D. B., … Mermelstein, R. J. (2017). Identifying "social smoking" U.S. young adults using an empirically-driven approach. *Addictive Behaviors*, *70*, 83–89. https://doi.org/10.1016/j.addbeh.2017.02.004

Walker, J. F., & Loprinzi, P. D. (2015). Adolescent and young adult smokers who self-identify as nonsmokers: relationship with cigarette-related withdrawal and cravings. *American Journal of Health Promotion*, 150825100010009. https://doi.org/10.4278/ajhp.141106-QUAN-559

Wang, Y., Sung, H.-Y., Yao, T., Lightwood, J., & Max, W. (2017). Factors associated with short-term transitions of non-daily smokers: Socio-demographic characteristics and other tobacco product use. *Addiction*, *112*(5), 864–872. https://doi.org/10.1111/add.13700

Waters, K., Harris, K., Hall, S., Nazir, N., & Waigandt, A. (2006). Characteristics of social smoking among college students. *Journal of American College Health*, *55*(3), 133–139. https://doi.org/10.3200/JACH.55.3.133-139

Waziry, R., Jawad, M., Ballout, R. A., Al Akel, M., & Akl, E. A. (2016). The effects of waterpipe tobacco smoking on health outcomes: An updated systematic review

and meta-analysis. *International Journal of Epidemiology*, dyw021. https://doi.org/10.1093/ije/dyw021

Wechsler, H., Rigotti, N. A., Gledhill-Hoyt, J., & Lee, H. (1998). Increased levels of cigarette use among college students: A cause for national concern. *JAMA*, *280*(19), 1673. https://doi.org/10.1001/jama.280.19.1673

Wetter, D. W., Kenford, S. L., Welsch, S. K., Smith, S. S., Fouladi, R. T., Fiore, M. C., & Baker, T. B. (2004). Prevalence and predictors of transitions in smoking behavior among college students. *Health Psychology*, *23*(2), 168–177. https://doi.org/10.1037/0278-6133.23.2.168

Wellman, R. J., DiFranza, J. R., & Wood, C. (2006). Tobacco chippers report diminished autonomy over smoking. *Addictive Behaviors*, *31*(4), 717–721. https://doi.org/10.1016/j.addbeh.2005.05.043

White, H. R., Bray, B. C., Fleming, C. B., & Catalano, R. F. (2009). Transitions into and out of light and intermittent smoking during emerging adulthood. *Nicotine and Tobacco Research*, *11*(2), 211–219. https://doi.org/10.1093/ntr/ntn017

White, H. R., Labouvie, E. W., & Papadaratsakis, V. (2005). Changes in substance use during the transition to adulthood: a comparison of college students and their noncollege age peers. *Journal of Drug Issues*, *35*(2), 281–306. https://doi.org/10.1177/002204260503500204

Wilson, D., Parsons, J., & Wakefield, M. (1999). The health-related quality-of-life of never smokers, ex-smokers, and light, moderate, and heavy smokers. *Preventive Medicine*, *29*(3), 139–144. https://doi.org/10.1006/pmed.1999.0523

Wolfson, M., Suerken, C. K., Egan, K. L., Sutfin, E. L., Reboussin, B. A., Wagoner, K. G., & Spangler, J. (2015). The role of smokeless tobacco use in smoking persistence among male college students. *The American Journal of Drug and Alcohol Abuse*, *41*(6), 541–546. https://doi.org/10.3109/00952990.2015.1078345

Wong, E. C., Haardörfer, R., Windle, M., & Berg, C. J. (2016). Distinct motives for use among polytobacco versus cigarette only users and among single tobacco product users. *Nicotine and Tobacco Research*, ntw284. https://doi.org/10.1093/ntr/ntw284

Yu, E., Saddleson, M., Murphy, J., Giovino, G., & Mahoney, M. (2017). Patterns of Polytobacco use among college students. *Health Behavior and Policy Review*, *4*(2), 173–181. https://doi.org/10.14485/HBPR.4.2.8

Zhu, S. H., Sun, J., Hawkins, S., Pierce, J., & Cummins, S. (2003). A population study of low-rate smokers: quitting history and instability over time. *Health Psychology*, *22*(3), 245–252.